Technical Report: NAVTRADEVCEN 69-C-0140-1

VOLUME I of II

# STUDY OF TRAINING DEVICE NEEDS FOR MEETING BASIC OFFICER TACTICS TRAINING REQUIREMENTS

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## ABSTRACT

This study was conducted to (1) identify tactical training needs and objectives of basic submarine officer personnel assigned to SSN and SSBN class submarines; (2) identify specific requirements for training materials which will meet the training objectives; and (3) provide functional requirements for recommended training devices. An operational analysis determined the job requirements, in terms of skills and knowledge, for each member of the fire control party. (The task analysis and skill and knowledge requirements are contained in a Classified Supplement, NAVTRADEVCEN 69-C-0140-1, Volume II.) Training objectives were determined from the skill and knowledge requirements, in conjunction with trainee input and output characteristics.

Training techniques and devices are recommended to meet the training objectives. The ability of existing facilities to meet the recommended device needs is discussed, and modifications are recommended. Finally, additional training devices are recommended to fulfill the needs not met by existing facilities. These new devices consist of a generalized individual trainer and a periscope visual task trainer.

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| Job analysis | | | | | | |

# FOREWORD

This technical report is the result of Contract N61339-69-C-0140 between the Naval Training Device Center and Electric Boat Division of General Dynamics. The purpose of this investigation was (a) to determine the training objectives for submarine officer initial training, (b) to determine specific requirements for supporting training materials which meet the desired training objectives, and (c) to provide functional descriptions for recommended training devices.

Task/system analyses, which are contained in a classified supplement, were developed and used to derive training objectives and recommendations for training techniques and devices. A procedure was developed to translate analysis information into functional training requirements which were combined to yield recommendations for device design. The recommendations include more realistic sonar simulation, introduction of system malfunctions, development of performance standards and new training devices including a periscope visual-task trainer and a generalized individual trainer. In addition, the task analysis information should be useful for future planning for submarine school curriculum development or updating.

The findings of this study will be reflected in the development of the next generation of submarine tactical training devices.

William B. Boney
WILLIAM B. BONEY
Project Psychologist

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## ACKNOWLEDGEMENTS

The authors wish to acknowledge the assistance and cooperation of CDR W. B. Hubbell, CDR R. E. Schlenzig, and LCDR W. D. Snell, of the Submarine School, U. S. Naval Submarine Base, Groton, Connecticut. These men provided some very useful suggestions to this study, and members of their staff aided in the conduct of observations on training devices.

# SECTION I

# INTRODUCTION

1.1 The fire control system on modern nuclear submarines has undergone fundamental changes over the past two decades. These system changes have resulted in increased demands on the operator, demands calling for increased mental processing tasks (e.g., decision making and data reduction). Projected fire control systems currently under development will continue this evolution in hardware and operator functions. The officer tactics training programs must keep pace with the operational system changes in terms of both curriculum and training devices. The objective of this study was to determine the need for tactics training devices to train basic officer personnel in accordance with present and projected fire control system design.

## 1.2 PROCEDURE

1.3 An operational job analysis was conducted to isolate job requirements for each member of the fire control party. This analysis led to the development of knowledge and skill requirements for each member, based on both theoretical and actual usage of the fire control system.

1.4 The present tactics training program for basic officers was reviewed, and from this, trainee (basic officer) input and output characteristics were determined. Objectives were developed to bridge the gap between trainee input characteristics and desired trainee output characteristics.

1.5 Each training objective was analyzed with respect to desired training techniques and/or devices to attain that objective; a list of devices and their specifications resulted. The present training facilities were evaluated and compared with the identified device needs. Existing device modifications and new devices were recommended which met the needs unfulfilled by the existing facilities.

## 1.6 RESULTS

1.7 Both individual and team training device needs were identified by the analysis. Present facilities are generally adequate for the team training needs, but not for individual training needs. A generalized individual trainer, capable of simulating the information displays and operator input-output needs for several operational devices, was recommended. This device is extremely flexible with regard to its simulator and training capabilities, and adequately meets projected individual training device needs. It is recommended that this device be developed and used in conjunction with basic and advanced officer training.

## SECTION II

## STATEMENT OF THE PROBLEM

2.1 The submarine's mission and fire control system have changed considerably over the past two decades. Whereas, once the primary mission was the sinking of enemy shipping, the primary mission now is the detection and destruction of enemy submarines. This change in mission emphasis led to changes in tactical theory; in fire control system capabilities, functions, and complexity; and in the tasks, skills, and knowledge required of human operators.

2.2 The tactical control problem is one of the most critical existing constraints on submarine weapon system effectiveness. A large part of this problem is the result of variability in system operator performance and,therefore, it can be reduced through more effective training (Pargo, 1968). The problem stems from many sources, several of which are discussed generally in the paragraphs following.

2.3 Of most significance is the inherent difficulty presented by the submarine tactical situation. The practically mandatory passive nature of the tracking system produces varying and conflicting data which, to date, requires statistical processing. Efforts to improve the fire control problem solution have led to a proliferation of data processing techniques and equipment to accomplish target motion analysis and weapon order generation. This, in turn, has led to increases in the number of human data transmitters, data processors, data recorders, and decision makers, thus increasing the mental tasks. It has also created a communications problem of considerable dimensions.

2.4 The requirement for a large number of people in the fire control party has accentuated the training problem to an extent beyond that attributable to increased numbers alone. It has led to divisions of labor and responsibilities and to differing levels of experience on the part of the operators. To make the most economical use of the existing training facilities, they have been designed to accommodate the widely varying experience levels of students such as prospective commanding officers, prospective executive officers, basic officers submarine school students, fire control parties from operating ships needing refresher training, and reserve training programs. Thus, the trainees may range from a seaman, learning the procedural steps of plotting, to a submarine Commanding Officer, knowledgeable in the complexities of target motion analysis and concerned with learning decision-making skills of a high order.

2.5 Another problem stems from the rapid rate of change in fire control systems and equipment which require trained operators. These changes range from equipment as much as 20 years old and still in use, to fire control systems being developed for new construction submarines (e.g.,Mk 113 Mod 10). Thus, the training system must adequately fill a wide range of operational needs. For example, the training needs of the Mk 113 Mod 10 will be considerably different from those of the Mk 113 Mod 6. (Although this study emphasized the training needs of the Mk 113 Mod 6, projected training needs were also considered.)

2.6 The submarine officer training programs must be continually updated to keep pace with the changing operational needs and state-of-the-art training techniques and devices.

# SECTION III

# PROCEDURE

3.1 An analysis of operational job requirements, considering both theoretical and actual system usage, was conducted for members of the fire control party. The levels of skill and knowledge required for each member of the party were then determined. Trainee input and output characteristics were determined, and the present training situation was reviewed with respect to training facilities and the training program. These efforts led to the development of training objectives from which the device recommendations were made. Included in the procedure was a review of training techniques which later led to device specifications.

3.2 ANALYSIS OF OPERATIONAL JOB REQUIREMENTS

3.3 A detailed, systematic analysis was conducted to isolate operational job requirements for each member of the fire control party. The paragraphs following describe the method by which a comprehensive review of the functions and interactions of the fire control party members was conducted.

3.4 DATA SOURCES. Several visits were made to the U.S. Naval Submarine School at New London, Conn., between April and December 1969. The purpose of these visits was to observe the Mk 113 Training Simulator in use and to gather data concerning:

1. the training procedure, including performance standards;
2. operational procedures for each member of the fire control party;
3. the nature and frequency of interactions among team members; and
4. problem areas in the training situation.

In addition to active observations, Electric Boat personnel engaged in discussions and interviews with the instructors and other personnel in the Tactics Department of the Submarine School.

3.5 A review of the following sources of existing data provided a great deal of information which was used in developing the operational job requirements:

1. Existing Operational Sequence Diagrams (OSDs) dealing with the fire control party and developed during previous studies (Henry and Jones, 1968; SUBIC, 1962).
2. Data from the Medical Research Laboratory (MRL) (1967), and Pargo (1968) studies on fire control system operation.

3. Existing technical manuals and operational doctrines, such as NAVORD OP 2985 and NAVPERS 10101.

4. Previous NTDC studies such as Hammell and Mara (1970).

5. Interviews with several persons employed at Electric Boat division, knowledgeable in the area of fire control.

3.6 TASK ANALYSIS. Data obtained from these sources was combined and developed into a detailed task analysis which is presented in Section I of the Classified Supplement. This task analysis defines, for each operator in the fire control party:

1. the discrete operational task;

2. the task type: decision making, communication, monitoring, inspection, procedure following, and/or constant perceptual motor activity;

3. the task criticality, using a 3-point scale, where 1 = low criticality, 2 = medium criticality, and 3 = extreme criticality;

4. the person(s) with whom the operator interacts in the performance of his tasks;

5. the means and/or mode by which these interactions take place;

6. the reason(s) for the interaction(s); and,

7. the criticality to the operator of the interaction, using the same 3-point scale as task criticality.

3.7 Thus, the task analysis describes the tasks performed by each operator in terms of these parameters. This analysis was useful because it combined, in a simplified format, a great deal of necessary information derived from several sources. Perhaps more importantly, it permitted comparison across operators in order to define the nature of their operational tasks with respect to the training situation.

3.8 Based on the task analysis and a decision-making analysis from a previous study (Hammell and Mara, 1970), generalizations were drawn concerning the functions performed by the following different groups in the fire control party. (Specific information on the tasks is found in the Classified Supplement.)

1. Tasks for the Approach Officer (AO) and Assistant Approach Officer (AAO), consist mainly of nonprocedural decision making (i.e., tactical decisions concerning ship welfare) and communication, with occasional monitoring and supervision (tables 1 and 2, Classified Supplement).

2. The Fire Control Coordinator and Plot Coordinator, performing more communications and supervisory tasks, together with many decision-making and inspection activities (tables 3 and 7, Classified Supplement).

3. Mk 113 console operators, perform a large percentage of lower level decision making (procedurally oriented) and data reduction, including continuous mental processing of data (tables 4, 5, and 6, Classified Supplement).

4. Plotting party members, perform some lower level decision making in conjunction with a large amount of procedural plotting tasks (tables 8, 9, 10, and 11, Classified Supplement).

3.9 These trends in the task analysis led to a logical breakdown of the fire control party into three levels of operators: (1) command and control, (2) fire control console operators, and (3) plotting party. This three-level breakdown will be discussed in greater detail in Section 3.15.

3.10 KNOWLEDGE AND SKILL REQUIREMENTS. Each of the identified tasks is composed of several knowledge and skill requirements. Specifically, in order to perform an iterative target motion analysis (TMA) on the Position Keeper (PK) (task 4.7, table 4 of the Classified Supplement), the operator must know several things about the data characteristics, PK operation, and TMA methods (knowledge requirements). In addition, the operator must be able to operate the PK, a skill requirement. Several knowledge and skill requirements may be necessary for each task. The skills and knowledge required of each operator must be acquired through either experience or training.

3.11 Individual operator skill and knowledge requirements, determined from the task analysis and decision-making analysis of the fire control party, are presented in Section II of the Classified Supplement. Requirements for the Assistant Approach Officer are included with those of the Approach Officer, since an Assistant Approach Officer is not always used in the Fire Control Party. The individual operator requirements represent a combination of those actually needed (i.e., those required for the system operation methods actually used at sea) and those desired (i.e., those required for the theoretical methods of system operation desired, but not always utilized, at sea). This distinction was made to illustrate the fact that experienced crews often operate the system hardware in other than the optimum manner (MRL report, 1967). The knowledge and skill requirements also fit roughly into the three levels discussed previously (Command and Control, Fire Control Console operators, and Plotting Party).

3.12 PERFORMANCE STANDARDS. To determine the type and level of training necessary for each operator, it was necessary first to assign performance standards to the operational tasks and their required skills and knowledge. Unfortunately, performance standards do not exist for most of the tasks performed by fire control party members; the most notable exception is periscope operation. Evaluation of the trainee's performance is based largely on subjective monitoring by the instructor.

(This statement is based on observations at the Sub School, New London, Conn., and interviews with Sub School staff.) In general then, performance measures and standards do not exist for basic officer tactics training, other than a criterion of "hit" or "miss".

3.13 In the absence of concrete performance standards then, it was necessary to develop an alternate measuring device. Based on available data, these performance standards take the form of specifications of the required levels of knowledge and skill. Where possible, especially in the skill level requirements, concrete performance standards of accuracy (such as read a dial correct to $\pm 1/2^{\circ}$) are included. These levels are included in the tables of skills and knowledge (Section II of the Classified Supplement) and are numbered in sequence with the knowledge and skill requirements to which they relate.

3.14 The levels of knowledge and skill developed in this study present relative performance differences and/or requirements among operators, thereby contributing to the three-level organization of the fire control party.

3.15 FIRE CONTROL PARTY ORGANIZATION. Having described the operational job requirements (tasks, skills, and knowledge) for each operator, it is then necessary to define the structure of the fire control party and see how the preceding analysis contributes to it.

3.16 Figure 1 is a block diagram of a typical fire control party, showing the general sequence of the standard ASW mission evolution. Three phases are described: contact, approach, and attack. In addition, the functions performed by each operator are indicated sequentially.

3.17 Unlike the primary mission of previous military periods, the present SSN primary mission is to seek out and destroy enemy submarines; therefore, operational and training emphasis is placed on the ASW mission. The block diagram begins with the contact phase where the initial plotting party tracks the target and establishes identification. After the target is classified as hostile, the approach phase begins. Iterative fire control problem solving takes place utilizing the full fire control party (this is typically the most difficult phase). The attack phase consists of determining the final solution parameters, converting these to weapon parameters, and making final own-ship maneuvers. The attack phase ends with weapon launch and evasive maneuvers, at which time the approach and/or attack phase may begin again.

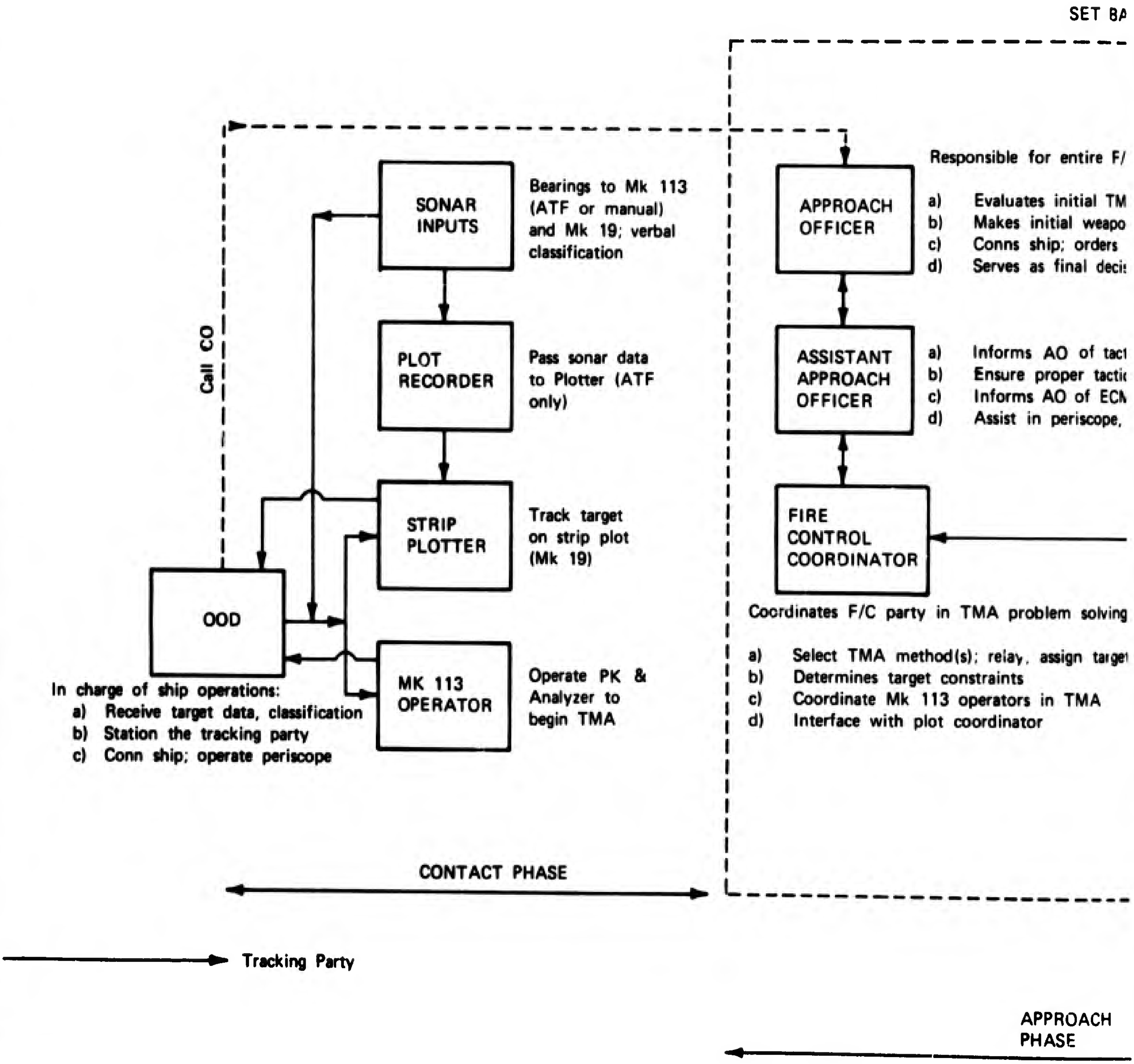
3.18 Figure 2, commonly known as a link diagram, illustrates the communications links between various operators and subgroups within the fire control party during a typical ASW mission. The strength (frequency) of the links between operators is indicated by the width of the lines; i.e., wide lines indicate strong links. (The relative widths of the lines were derived from data on fire control party communications during simulator training (MRL, 1967).) The subjects were experienced fire control party crews working on typical ASW problems.

3.19 Note the several distinct areas of communication interaction in figure 2. The plotting party is one separate group, connected to the rest of the fire control party through the Fire Control Coordinator-Plot Coordinator link. The fire control console operators are also a distinct group. Both the plotting party and fire control console operators are connected to the Approach Officer (and ship control functions) through the Fire Control Coordinator-Approach Officer link. This figure illustrates the construction of the fire control party in terms of subgroups and interactive relationships. From these two figures, as well as from the previous discussion on operator tasks, it is apparent that a three-level fire control party organization has been identified. These levels are described in more detail in the paragraphs following.

3.20 Command and Control. This group includes the Approach Officer, Assistant AO, and, to a large extent, the Fire Control Coordinator. These people perform the majority of non-procedurally oriented decision tasks. Their functions are involved with ship handling and control, approach and attack tactics, weapon and weapon order selection, evasive actions, evaluation of TMA solution goodness, and supervision of the TMA and other aspects of the fire control party. Their involvement with actual fire control party operation is limited largely to inspection and occasional monitoring. They do not operate consoles, nor do they perform much data reduction. The Fire Control Coordinator is the only exception to this; he performs a large number of procedural duties, as well as acting as a high-level decision maker. The command and control group is composed of officers, usually the Commanding Officer, Executive Officer, and Weapons Officer.

3.21 Fire Control Console Operators. This group is largely composed of operating personnel, usually officers and high rated enlisted men. Responsible for complete operation of the Mk 113 and weapons control systems, their tasks are composed of lower order decision making, relating mainly to equipment operation and data reduction; data assimilation and reduction; setup procedures; TMA problem solving; setting of weapon orders and constraints; weapon course keeping; monitoring of hardware operation; analog and digital computer interface; and processing of sensor information. These men, although not possessing the in-depth tactical knowledge of the command and control group, must possess a high level of individual skill and knowledge in relation to operation of the hardware and to TMA problem solving. The Fire Control Coordinator supervises their operations; he must bridge the gap between these operators and the command and control group to promote effective fire control party operation.

A


SET BA
Call CO
SONAR INPUTS
Bearings to Mk 113 (ATF or manual) and Mk 19; verbal classification
PLOT RECORDER
Pass sonar data to Plotter (ATF only)
STRIP PLOTTER
Track target on strip plot (Mk 19)
OOD
MK 113 OPERATOR
Operate PK & Analyzer to begin TMA
In charge of ship operations:
a) Receive target data, classification
b) Station the tracking party
c) Conn ship; operate periscope
APPROACH OFFICER
Responsible for entire F/
a) Evaluates initial TM
b) Makes initial weapo
c) Conns ship; orders
d) Serves as final deci
ASSISTANT APPROACH OFFICER
a) Informs AO of tact
b) Ensure proper tacti
c) Informs AO of ECM
d) Assist in periscope,
FIRE CONTROL COORDINATOR
Coordinates F/C party in TMA problem solving
a) Select TMA method(s); relay, assign target
b) Determines target constraints
c) Coordinate Mk 113 operators in TMA
d) Interface with plot coordinator
CONTACT PHASE
Tracking Party
APPROACH PHASE

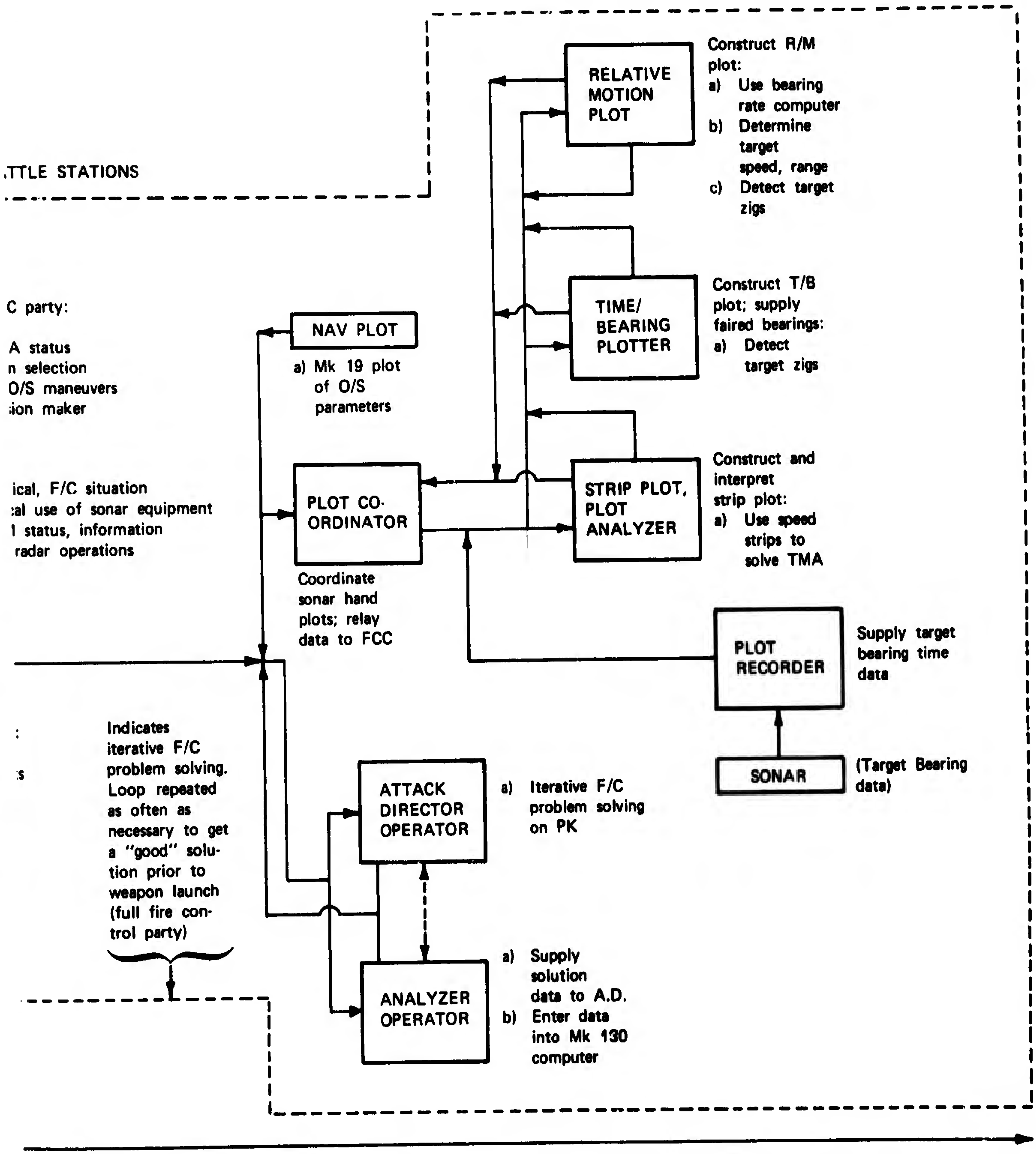
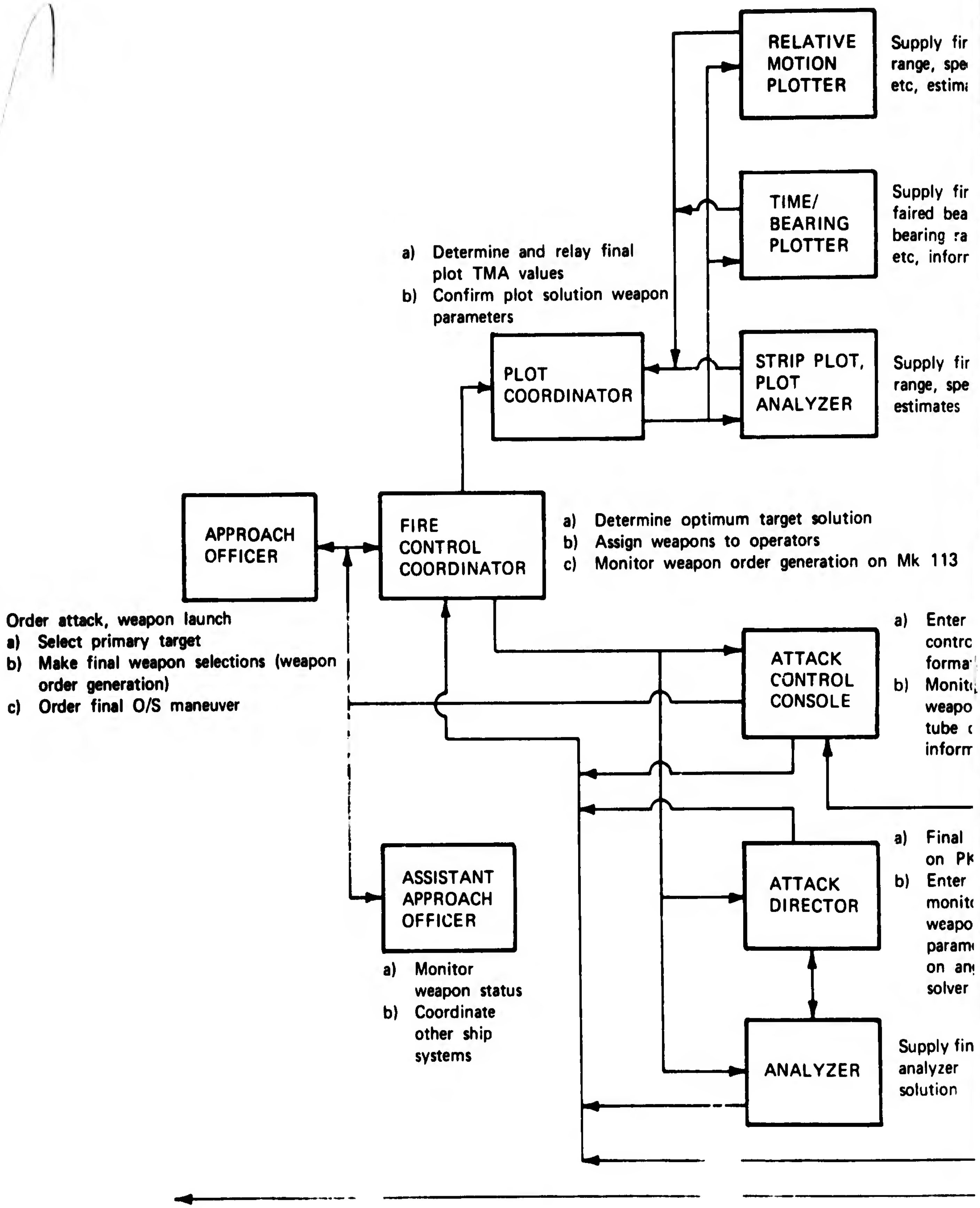



Figure 1. Block Diagram of Typical ASW Mission Evolution
(Sheet 1)


RELATIVE MOTION PLOTTER
Supply fir
range, spe
etc, estim
TIME/ BEARING PLOTTER
Supply fir
faired bea
bearing ra
etc, inforr
a) Determine and relay final plot TMA values
b) Confirm plot solution weapon parameters
PLOT COORDINATOR
STRIP PLOT, PLOT ANALYZER
Supply fir
range, spe
estimates
APPROACH OFFICER
FIRE CONTROL COORDINATOR
a) Determine optimum target solution
b) Assign weapons to operators
c) Monitor weapon order generation on Mk 113
Order attack, weapon launch
a) Select primary target
b) Make final weapon selections (weapon order generation)
c) Order final O/S maneuver
ATTACK CONTROL CONSOLE
a) Enter
contro
forma
b) Monit
weapo
tube
inform
ASSISTANT APPROACH OFFICER
a) Monitor weapon status
b) Coordinate other ship systems
ATTACK DIRECTOR
a) Final
on Pk
b) Enter
monit
weapo
param
on an
solver
ANALYZER
Supply fin
analyzer
solution

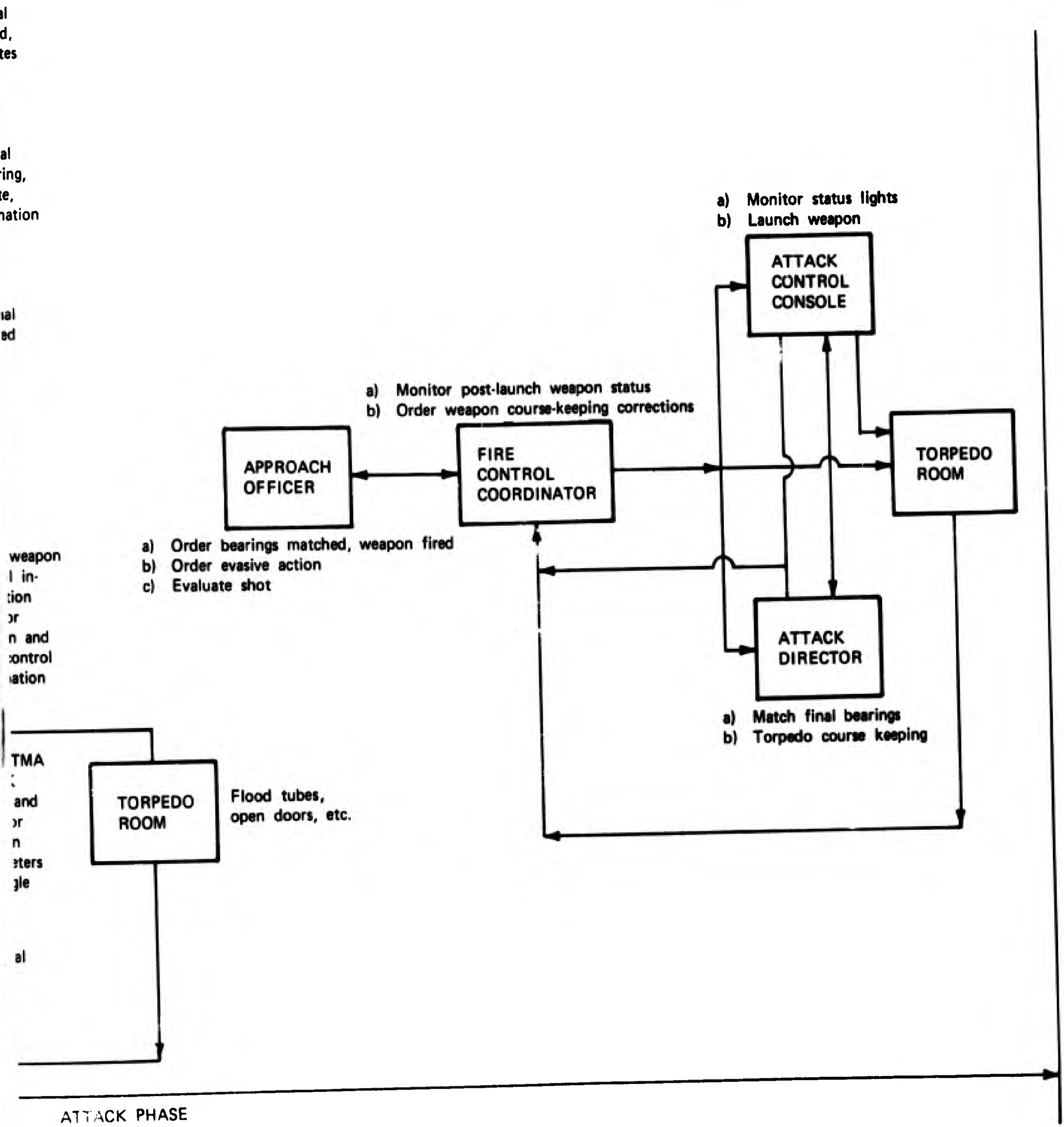



Figure 1. Block Diagram of Typical ASW. Mission Evolution
(Sheet 2)

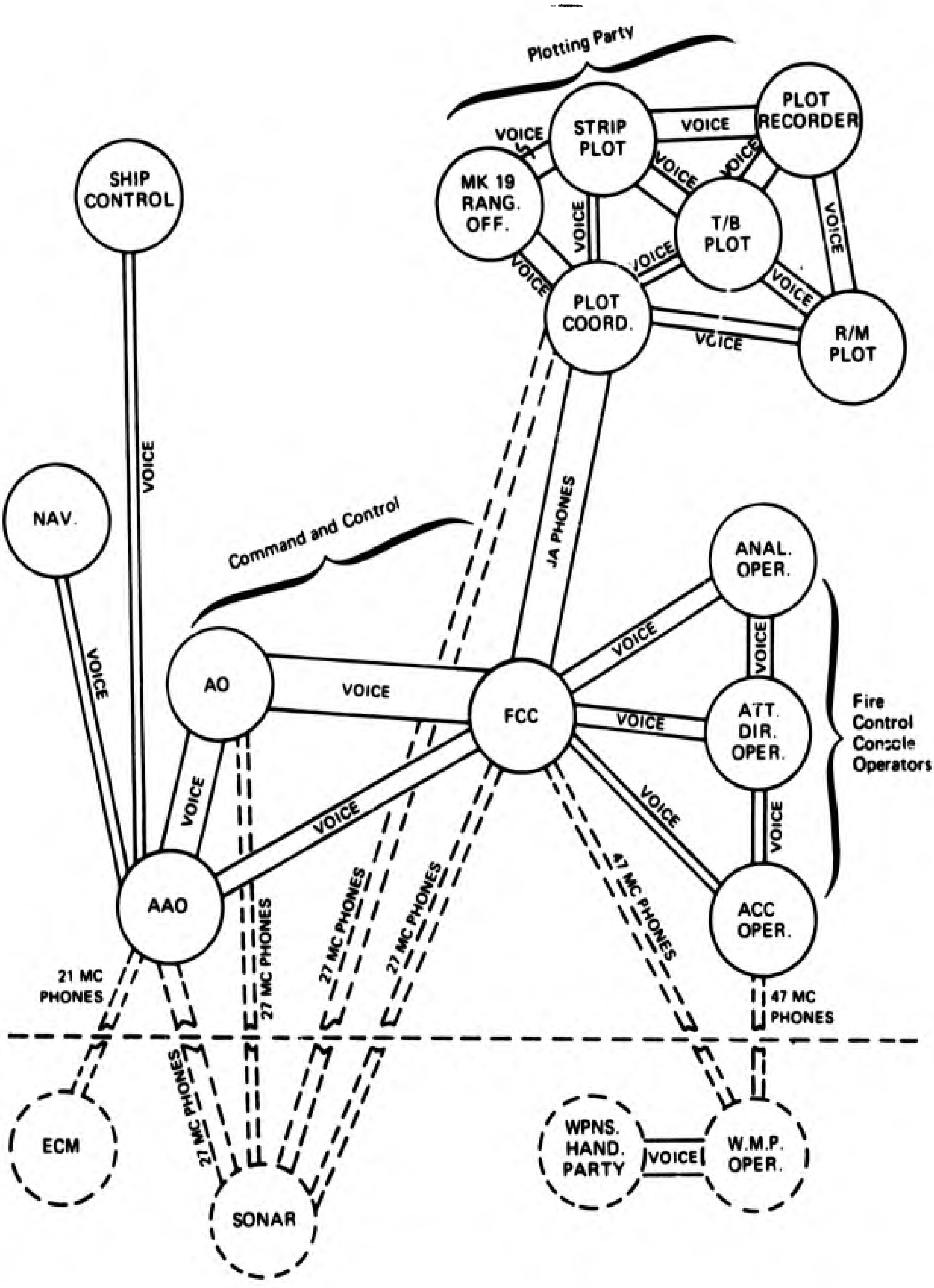



Figure 2. Link Diagram Illustrating Communications Links Among Members and Groups in the Fire Control Party

3.22 Plotting Party. Except for the Plot Coordinator and Strip Ranging Officer, this group of operators is composed of lower rated enlisted men. Their responsibility is to develop geographical tactical presentations and paper and pencil TMA, and to confirm estimates of target parameters. They perform some decision-making duties (task analysis, Section I of the Classified Supplement), but they are quite limited and of a lower order (more procedural) than those in the command and control and fire control console operator groups. The Plot Coordinator and Strip Ranging Officer are the primary decision makers in the plotting party. The Plot Coordinator comes under the Fire Control Coordinator and is responsible for directing the plotting functions and evaluating their results. The Strip Ranging Officer works for a TMA solution on the strip plot, in conjunction with the strip plotter.

3.23 Degree of Functional Overlapping. While the lines between these three personnel groups within the fire control party are fairly well drawn, it is apparent that there is still considerable overlap in the skill and knowledge requirements, exemplified in the case of the Fire Control Coordinator and, to some extent, by the Plot Coordinator. Nevertheless, the three groups still occupy quite distinct areas.

3.24 IMPLICATIONS FOR TRAINING. A realistic training program, to be effective, must relate to both the theoretical and actual (i.e., determined from experience) system usage. This relationship is reflected in both the task analysis and the skill and knowledge requirements.

3.25 Similarly, a suitable training program must meet the needs created by present operator deficiencies. For instance, studies (MRL, 1967; Pargo, 1968) have shown a lack of individual skill and knowledge in TMA problem solving and adapting to unanticipated situations such as an equipment malfunction. Also, better team communication and coordination are desirable, as evidenced by the MRL (1967) study and observations of experienced crews practicing on fire control party simulators.

3.26 Thus, an improved training program must, first, answer the needs of both individual and team training. Second, it must accommodate both formal (textbook) and practical (experience) methods and inputs. Third, in order for skills to be comprehensive, the program must include comprehensive training in the use of equipment in a degraded or malfunctioning condition.

3.27 Training objectives and devices for meeting these conditions are recommended and discussed in subsequent sections.

3.28 TRAINEE CHARACTERISTICS

3.29 Training objectives must be derived from the operator skill and knowledge requirements discussed in Section 3.2. These objectives must bridge the gap between the skills and knowledge the new trainee possesses and the skills and knowledge desired of a basic officer. The basic officer training program must begin at the trainee input characteristics level and continue until trainees reach the level of desired output characteristics (i.e., at the completion of basic officer tactics training).

3.30 TRAINEE INPUT CHARACTERISTICS. New basic officers come from several different training programs. Table 1 is a breakdown of the most recent group, typical of most of the entering groups. Naval Academy graduates comprise the majority of basic officers (over 50 percent), with NROTC making up about 35 percent and Officer Candidate School, less than 10 percent. The Naval Enlisted Scientific Education Program is a special program not usually represented by entering basic officers. One such officer was present in the group considered, however. Of this representative group (82 men), 8 were Ensigns and 74 were LTJGs. Fifty-one held technical degrees, with the remaining degrees in social sciences and arts.

TABLE 1. COMPOSITION OF TYPICAL BASIC OFFICER GROUP ENTERING SOIC

| Source | Number | Percentage |
|---|---|---|
| Naval Academy | 45 | 54.8 |
| NROTC | 29 | 35.3 |
| Officer Candidate School* | 6 | 7.3 |
| Naval Enlisted Scientific Education Program | 1 | 1.2 |
| TOTAL | 82 | 100 |

*Graduates of Officer Candidate School who came to SOIC are college graduates who did not have NROTC training.

3.31 Trainee performance as a function of academic background is not available; however, according to Sub School personnel, the lack of a firm technical foundation does not seem to present any abnormal difficulty. Dropouts for technical reasons amounted to about 2-1/2 percent last year (13 out of 548). The Sub School staff expressed the belief that any deficiency due to background diversity can be overcome with a small amount of individual effort. Trainees are supposed to enter basic officer training with knowledge about relative motion, basic geometry, etc; however, a course pre-test has indicated that this is not the case. Training must therefore begin at the level of basic geometry.

3.32 Formerly, basic officer tactics training consisted of one course. In early 1969, because of manpower requirements, the basic officer training course was eliminated. Rather than a full basic officer training course, entering officers (those coming directly from Nuclear Power School) now receive a short indoctrination course - Submarine Officers Indoctrination Course (SOIC). Following SOIC, the officers go to sea for two years on an SSN or SSBN submarine. During this time they may or may not receive additional training and/or fire control party experience. For example, an engineering officer on an SSBN may remain aft for two years, in which case he would receive no fire control party experience. Conversely, an SSN officer may be a member of the fire control party, in which case he may become extremely proficient in target motion analysis. After two years at sea, the officers planning to stay in the Navy go to the Submarine Officers Advanced Course (SOAC). (These courses will be covered in greater detail in Section 3.40).

3.33 Generally speaking, some amount of basic officer training is expected to be completed in the SOAC course. An officer who has completed basic officer training is expected to possess a certain level of skills and knowledge, attained through training or experience, or a combination of training and experience. The SOIC course is not sufficient to impart this desired level of skills and knowledge for submarine officer qualification, however. Between the time of the SOIC and SOAC courses, some officers will receive additional tactics training and/or experience at sea. Some will not. The officers entering SOAC will therefore possess a wide range of skills and knowledge, levels ranging from that of the entering basic officer trainee to that of the officer above the basic officer level. Most of the officers entering SOAC will not have reached this basic officer proficiency level. Thus, the SOAC will have to provide some amount of basic officer training, the amount depending on the individual's level of proficiency.

3.34 Since this SOIC/SOAC training program is so new, SOAC courses have not yet been offered in their present format. Thus, data is not available on entering trainees. Figure 3 represents the projected trainee-training program structure. Approximately 450 trainees (in 5 or 6 groups) will enter SOIC training each year. Of this number, 40 percent are expected to go to SSNs and 60 percent to SSBNs. About half of each group will be assigned forward; i.e., 50 percent are expected to receive onboard experience. Those assigned forward on the SSBNs are likely to act only as plot officers in the fire control party. Although SSBNs have mandatory refresher training, the fire control system is not emphasized. The officers on the SSNs are likely therefore to receive a greater amount of fire control party training than those on the SSBNs. From both groups, a relatively small percentage (less than 10 percent) will receive an intensive one-week Mk 113 familiarization course. After two years of at-sea duty, 42 percent are expected to enter the SOAC course. It is further expected that slightly better than half of the SOAC candidates will have had Mk 113 training and/or experience.

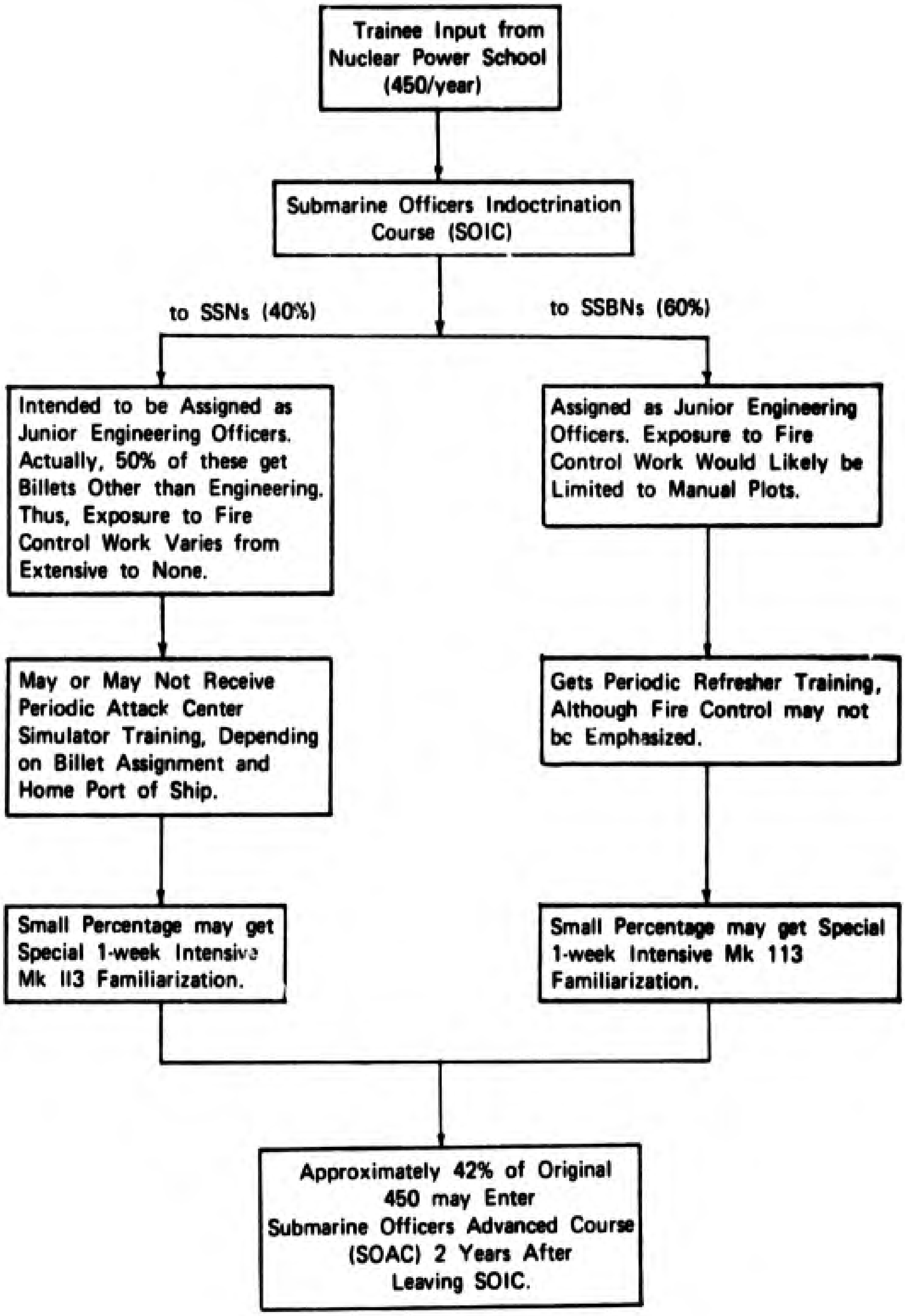



Figure 3. Basic Officer Trainee-Training Program Structure

3.35 Thus, the entering group will probably be at varying levels of proficiency. It is doubtful that any officer, during the period between SOIC and SOAC, will attain the level of proficiency previously required for submarine officer qualification (i.e., at the completion of basic officer training).

3.36 TRAINEE OUTPUT CHARACTERISTICS. As noted previously, trainee (basic officer) output characteristics are based on the level of proficiency required for submarine officer qualification. The attainment of this proficiency level may be the result of training or experience, or some combination of training and experience. Thus, the desired output level is independent of the means by which it is attained. In this respect, trainee (basic officer) output characteristics may be defined without regard to the structure of the training program.

3.37 The overall objectives of basic officer training have been determined from discussions with Sub School personnel, other experienced personnel, a review of appropriate publications (e.g., NAVPERS 10101), and a review of operator job requirements in an ASW mission. The officer who has completed basic officer training is expected to be able to adequately fill any position in the fire control party, including Fire Control Coordinator and Approach Officer. This has been interpreted to mean the basic officer must possess the high level of proficiency (skill and knowledge) required of any of the plotting party and/or fire control console positions. It is unrealistic, however, to assume that a basic officer could completely and adequately fill the Fire Control Coordinator's, Assistant Approach Officer's, or Approach Officer's position. The basic officer should be able to perform the functions of each of these three positions, but not to the same level of proficiency as personnel already experienced in those positions.

3.38 Thus, the desired basic officer output characteristics can be viewed in terms of the level of knowledge and skills required of the three groups in the fire control party (Section 3.2). Upon completion of basic officer tactics training, the basic officer should possess a level of skill and knowledge commensurate with the level required of each member of the fire control console operators and plotting party groups. In addition, the basic officer should possess the skills and knowledge required of the command and control group, although at a lower level.

3.39 The basic officer's functions in the fire control party center around TMA. The knowledge and skills of the fire control console and plotting party groups are concerned with TMA. The command and control group skills and knowledge are concerned with TMA, weapons, sensors, ship handling, encounter tactics, etc. Thus, basic officer training should primarily emphasize TMA, and, to a lesser extent, emphasize weapons, sensors, and ship handling. The basic officer must be able to fulfill the needs of every fire control party position, with the exception of the command and control group. Thus, from the skills and knowledges listed for each operator, together with the trainee input and output characteristics, the basic officer training objectives can be determined.

## 3.40 PRESENT TRAINING SITUATION

3.41 Several visits were made to the Weapons and Tactics Division of the Sub School, U.S. Naval Submarine Base, New London, Conn., during this study. These visits were for the purpose of observing various phases of basic officer training and/or for discussions with Sub School personnel. This section summarizes the present basic officer training program and existing training facilities.

3.42 TRAINING COURSES. In the past, basic officer training consisted of a comprehensive six-month course. Responsive to present manpower needs, the six-month course has been shortened to five weeks (the SOIC course). This shortened indoctrination course, obviously, cannot adequately develop the knowledge and skills required of a basic officer. The 40 hours devoted to weapons and tactics are intended to familiarize the student with submarine weapons systems and the fire control problem geometry. Mk 113 operation is demonstrated only once during this course.

3.43 As indicated previously, the intervening two-year period between SOIC and SOAC is one of informal training, for the most part. SSN officers stand a good chance (50 percent chance) of getting considerable onboard fire control party experience. Conversely, SSBN officers do not have as good a chance for fire control party training at sea; however, they receive a considerable amount of refresher training. As yet, the effects of this two-year interim period cannot be determined with regard to officer proficiency. It is doubtful, however, that during this period an officer will attain the level of proficiency previously required for submarine officer qualification. Thus, SOAC will have to provide training in some basic officer skills and knowledge.

3.44 The SOAC has not yet been offered and the curriculum is not yet firmly established; however, it will be approximately six months long, eleven weeks of which will be devoted to tactics and weapons. The basic tactics portion of the course will be organized under a Weapons Systems Division of the Basic Submarine Officers Department. The purpose of this portion will be to train qualified submarine officers in the functions, operations, and effective employment of the BQQ-2 Sonar System, Mk 113 Fire Control System, Mk 48 Weapons System, and the SUBROC missile. The course will provide extensive practical training for Approach Officers.

3.45 The objective of the SOAC course is to provide advanced officer training (i.e., all aspects of the fire control situation, including Approach Officer training). This objective goes beyond basic officer qualification training. Thus, the SOAC course may initially have to be within the scope of basic officer training, primarily for those who have served as engineering officers. After the initial stages, the SOAC course may move beyond the basic officer level to advanced levels of training.

3.46 Basic officer training, then, is spread over a considerable period of time, covering SOIC, refresher training and at-sea experience, and SOAC. Thus, each of these training programs must share in the objectives of basic officer training. In this respect, training facilities should be provided to implement basic officer training, covering the needs of the respective training programs (i.e., SOIC, refresher training, and SOAC). Logically, the training equipment used in the basic portion may also be useful for the more advanced command function training (decision-making training).

3.47 Due to the uncertain nature of training received during the two-year period between SOIC and SOAC, diversified levels of trainee input are expected. The need clearly exists in SOAC, therefore, for some form of individualized training, the level being commensurate with the trainee's skill and knowledge levels.

3.48 Eventually, it is expected that the re-structured basic officer training program will place emphasis on at-sea experience and refresher training, in terms of meeting some of the basic officer training objectives. However, due to the relative newness of the program, it is too early to assess the effects.

3.49 TRAINING FACILITIES. The present training functions at Sub School encompass a number of different training divisions, of which the Weapons and Tactics Division is a part. Presently, both diesel and nuclear submarine training are given, with diesel-oriented training to be eventually phased out. The following training facilities are oriented toward both nuclear and diesel fire control systems.

1. For diesel submarine training:
   - Two plotting rooms with a total of 26 Mk 7 plotters for practicing manual plotting techniques.
   - Two Target Data Computer (TDC) rooms containing eight Mk 4 TDCs in each room.
   - Two mechanically driven attack teachers which simulate TDC systems and periscopes.
   - One electronic attack teacher.
2. For nuclear submarine training (including refresher training):
   - One Mk 112 attack center simulator.
   - Three Mk 113 attack center simulators, one of which has a dynamic periscope simulator.

3.50 The attack center simulators are electronically controlled by both analog and digital computers. Differing amounts of flexibility are incorporated into each trainer.

3.51 The diesel training facilities are generally considered as adequate. Since diesel submarines will eventually be phased out, no attempt has been made to review the adequacy of these facilities. Several of the diesel training facilities are used for training nuclear submarine basic officers, however, namely the Mk 7 plots and one attack teacher for periscope training.

3.52 The nuclear submarine basic officers do not receive individual training on the various Mk 113 system devices, in contrast to diesel submarine officers who train on Mk 4 TDCs. Rather, all Mk 113 training is confined to the attack center team trainers. This is an obvious deficiency in the existing facilities. Basic officers must develop individual skills in the team training environment. This deficiency leads to less than optimum training; there is usually only one instructor for 5 or 10 students, each of whom needs individual training. Also, the lack of individual skills impedes team development. The need clearly exists, therefore, for individual Mk 113 training devices.

3.53 The nature of an operator's task on the Mk 113 system is different from that of the earlier TDC systems. In the earlier system, the operator tasks were concerned with psychomotor skills (e.g., monitor for "spots," adjusting the knobs accordingly, in a continuous fashion). In contrast, the Mk 113 operators must concentrate on performing mental analyses (e.g., data reduction and information processing) in accordance with the demands of the system. Thus, training emphasis should not be placed on the "knobs and dials" aspects, but rather on the "mental analysis" aspect. Training devices should be oriented to meet this need.

3.54 The attack center team trainers are used for basic officer training, as well as for refresher and advanced training. Thus, they operate on a full schedule, and cannot be used for longer periods of basic officer training.

3.55 Several of the areas covered in tactics training are covered in greater detail by other Sub School divisions, and, therefore, their inclusion in the tactics curriculum should be only to the extent they directly affect TMA (i.e., the major training objective of basic officer tactics training). Several examples are: (1) sensors theory (sonar) training is handled by the Operations Division; (2) weapons theory training is handled by the weapons group of the Weapons and Tactics Division; and (3) ship maneuvering theory is covered by the Executive Division.

3.56 In summary, then, Sections 3-28 and 3-40 contained an overview of the present training situation, including trainee input and output characteristics, the training course structure, and existing training facilities. The existing facilities will be considered in subsequent sections in relation to their fulfillment of the training system needs.

3.57 TRAINING LITERATURE REVIEW

3.58 Training variables meriting consideration when designing a training system are training techniques and device design parameters. These variables, and the levels therein, should be applied differentially to the training situation, depending on the training objectives, skills and knowledge to be trained, state of the art in training technology, and cost effectiveness considerations. This section presents a brief review of the training parameters considered in this study, and discusses their potential to basic officer training.

3.59 INDIVIDUAL VS TEAM TRAINING. Relatively little research has been performed on individual vs team training. The research which has been completed is somewhat conflicting with regard to when individual or team training is preferred (Alexander and Cooperband, 1965; Briggs and Naylor, 1964; Briggs and Johnston, 1967; Eckstrand, 1964; Horrocks, Hermann and Krug, 1961; Kennedy, 1962; Kinkade, Kidd and Ranc, 1965; Siegel and Federman, 1968; and Tallmadge, Shearer, and Greenberg, 1968). In evaluating the above literature, the following were determined, although not universally agreed upon:

1. Individual training is necessary for the development of individual skills, including interactive skills.

2. Team training is necessary for the molding of these individual skills into a team context.

With respect to basic officer training, both individual and team training is necessary. Individual training should precede team training so as not to have an individual skill deficiency interfere with the development of team skills.

3.60 FEEDBACK. Feedback is generally accepted as an aid to learning and task performance (Annett, 1961; Briggs and Johnston, 1967; Jeantheau and Anderson, 1966; Kinkade, Kidd and Ranc, 1965; Klaus, Grant and Glaser, 1965; Rosenberg and Hall, 1958; Sidorsky and Simoneau, 1970; and Smode, Gruber, and Ely, 1963). Three types of feedback exist in most training situations:

1. Intrinsic feedback - that which is received from the trainee's own movements.

2. Action feedback - that which is received from the system.

3. Achievement feedback - that which is provided by a source external to the system.

Feedback can be immediate, as is usually the case with intrinsic feedback, or delayed. It can also result from an individual's performance (direct), or from the team's performance (confounded).

3.61 Intrinsic feedback is not usually under control of the training device, whereas action feedback is. System fidelity often determines the type and amount of action feedback. Achievement feedback is provided by the instructor or the training device. It is most useful in the earlier phases of training. In fact, it may be undesirable in the later phases of training (Klaus, Grant and Glaser, 1965).

3.62 Direct achievement feedback should be provided, where feasible, in the early phases of basic officer training, especially where fidelity and action feedback are low. Such direct feedback should be minimized in the later phases of basic officer training, where fidelity and action feedback are higher.

3.63 FIDELITY. Training task fidelity has been identified by many researchers as an important parameter associated with transfer of training (Briggs and Johnston, 1967; Briggs and Naylor, 1964; Cox, Wood, Boren and Thome, 1965; Crawford, 1966; Eckstrand, 1964; Foster, 1967; Jeantheau and Anderson, 1966; Micheli, 1967; Sidorsky and Simoneau, 1970; Smith, 1966; and Smode, Gruber, and Ely, 1963). Conversely, hardware fidelity is not considered essential by most researchers; that is, the training situation should provide behavioral similarity, but not necessarily physical similarity, to the operational situation.

3.64 Some amount of disagreement exists among researchers as to which behavioral parameters should and should not be replicated with high fidelity. It appears that high fidelity is important in the explicit variables being trained, although not so in other situational variables. For example, if the objective is to train an operator in the plotting of faired bearing lines, bearing information should be degraded rather than perfect (i.e., degraded bearing information is more realistic). Conversely, if the objective is to train the operator in solving own ship-target geometrical problems, high fidelity (i.e., realistically degraded) sonar bearings are not necessary; realistic sonar information would not aid in the development of specific geometrical problem-solving skills.

3.65 In many cases, physical (hardware) fidelity may be necessary to attain behavioral similarity to the operational situation. This requirement usually occurs in the latter phases of training when the trainees must combine previously learned complex behaviors for which complex stimuli are necessary. Often, such stimuli can only be provided by a high fidelity hardware system. This situation occurs in team training for an approach and attack mission.

3.66 Time is a fidelity variable used on all training devices. Often, time is of high fidelity when it need not be; in such cases, the cost effectiveness of the device is reduced. A study by Sidorsky and Simoneau (1970) showed that time can be shortened without adversely affecting training. For example, in training basic skills or knowledge such as how to make use of the angle-on-the-bow estimate in TMA problem solving on the PK, extended time periods are not necessary. Several short problems may be of greater benefit than one long problem. In the latter phases of training, however, timing, coordination, etc, become more important and, thus, time fidelity is of greater importance. In addition, time may be manipulated to produce different situational conditions, such as increasing stress by decreasing the time in which to obtain a solution.

3.67 STRESS. Considerable research has been performed on the stress effects of various learning situations. Relatively little research has been conducted, however, on the introduction of artificial stress into the learning situation. It is generally conceded that optimum learning occurs under conditions of low stress, although this is not always true (Smode, Gruber and Ely, 1963). Smode, et al, contend that stress has a facilitating effect in simple learning situations, and an adverse effect in complex learning situations. Since the majority of tasks encountered in the fire control party are complex, training should generally be at low stress levels.

3.68 Other factors must be considered, however, namely, the operational performance environment. Operational performance becomes most important under high stress conditions such as wartime encounters. Often, after acquiring a high level of skill, an operator will regress to undesirable responses when placed in a stress situation (Fitts, 1961). Training must be geared to eliminate this breakdown wherever possible. In addition, Crawford (1966) contends that some amount of high stress in a high-fidelity simulator training session is desirable, although not always possible to achieve.

3.69 The majority of basic officer training should occur under conditions of low stress. After the trainees have mastered their individual and team skills, stress should be introduced in team training situations, preferably on a high fidelity device providing considerable feedback (Smode, et al, 1963). Several types of stress can be introduced:

1. Information variability, such as sonar bearing variability.
2. Problem complexity, such as additional and/or unusual targets.
3. System degradation, such as equipment casualties.
4. Environmental interference, such as noise, blinking lights, etc.
5. Target capabilities, such as level of sensing and tactics the target is capable of using against own ship.
6. Secondary task loadings, giving operators more tasks to perform than they normally have.
7. A superior officer placed in the area as an observer (Navy Captain, Head of Tactics, etc ).
8. Time manipulation, such as decreasing the time available for a solution.

3.70 The amount of stress can be regulated by providing different levels of these stresses and by varying the combinations. Appropriate studies should be conducted to determine the most desirable types, levels, and combinations for introduction into training.

3.71 ADAPTIVE TRAINING. Adaptive training is a technique whereby the difficulty, and/or the complexity, of the training task varies as a function of operator performance. Adaptive training has the potential of being superior to fixed training (Kelley, 1969) in that the level of difficulty increases as the individual trainee's level of proficiency increases. Most adaptive training research has been conducted in the area of psychomotor skills (such as a tracking task), with relatively little research into the development of adaptive techniques for cognitive tasks (information processing) and other complex operational tasks (Ellis, Lowes, and Matheny, 1967; and Kelley and Prosin, 1969). This deficiency in the type of tasks common to most military systems is because of a lack of knowledge on adaptive performance measurement techniques for complex operational tasks (Kelley and Prosin, 1969).

3.72 The variables which must be considered in an adaptive system are:

1. criterion parameter(s) on which to judge the trainee's performance;

2. a valid and reliable means of measuring trainee performance on each identified criterion;

3. standard performance levels to determine when changes in task difficulty and/or complexity level should be made.

4. adaptive tasks to be changed in accordance with measured performance; and

5. adaptive logic for relating performance changes to changes in the adaptive tasks (Caro, 1969; Ellis, et al, 1967; and Kelley and Prosin, 1969).

3.73 Little data on operational and training systems has been collected from which these variables can be determined. Kelley and Prosin discuss several methods of performance measurement, and conclude that much more practical experience is needed to apply such measures to military systems. Knoop (1966) suggests that computer-aided training systems be constructed and utilized as experimental tools for the development of criteria and measures which will eventually be inputed to the system. Kelley and Wargo (1968) list several task variables amenable to adaptive control and four different adaptive logic schemas.

3.74 The use of adaptive training in the basic officer program is limited by a lack of knowledge and data concerning the variables listed above (e.g., performance measures) with respect to operator skills in the submarine fire control party. A study should be conducted to determine such measures for all of the tasks performed by the fire control party. Standards of performance should be set, based on the developed performance measures. This type of study should be undertaken regardless of whether adaptive training is being considered; i.e., for improved training, performance measures and standards should be developed. Prospective adaptive variables (e.g., encounter complexity, information variability, and target actions) are available for each operator position. Increment size, levels of the variable,

variable combinations, and their relationship to the performance monitoring function(s) must be determined, however, before the adaptive variables can be applied to basic officer training.

3.75 Adaptive training in complex operational tasks appears feasible on the part-task basis (Caro, 1969; and Kelley and Prosin, 1969). Part-task adaptive training occurs when a complex series of tasks (e.g., the tasks of the attack director operator) are broken down into several part-task groups, for example, weapon course keeping and iterative solving on a bearings-only solution. Before such a program can be instituted, however, the variables discussed above must be considered.

3.76 Adaptive training can be, and often is, implemented on the basis of changing complexity and/or difficulty from one problem to the next, rather than adaptively changing parameters during a problem (such as in a simple tracking task). This type of adaptive change appears more feasible for complex operational tasks and, thus, for basic officer training.

3.77 In summary, adaptive training appears both feasible and desirable for basic officer training. Before an adaptive program could be implemented, however, a study must be conducted to determine the proper criteria, develop performance measures and standards, and determine adaptive variables and logic.

# SECTION IV

# RESULTS

4.1 The preceding analyses led to the development of basic officer training objectives (given in Appendix A). This section discusses these training objectives and determines the training program requirements, specified in terms of training techniques and devices necessary for meeting each of the training objectives. In the context of this study, a training device is assumed to be any vehicle by which training is implemented (e.g., classroom instruction, textbook, and high fidelity team simulator). The training program requirements, although specifying device parameters, were determined without regard to particular hardware. This was done to avoid having hardware design bias the determination of desired device parameters. (Specific hardware requirements are discussed in Section V.)

## 4.2 TRAINING OBJECTIVES

4.3 Basic officer training objectives were developed from the skills and knowledge (Section II of the Classified Supplement) identified in the operational job analysis (Section 3.2). These objectives reflect the desired trainee output characteristics in terms of the knowledge and skills possessed by each of the three fire control party groups (command and control, Mk 113 fire control console operators, and plotting party) and required of trainees who have completed basic officer tactics training. The objectives emphasize Target Motion Analysis (TMA) knowledge and skills on all the Mk 113 devices and plots. To a lesser extent, they emphasize weapon selection, ship handling, and use of sensors. (These functions are typically performed by the command and control group, and therefore are not of primary interest in basic officer tactics training.)

4.4 Skills and knowledge taught by other Sub School divisions, though pertinent to tactics training, have been de-emphasized in the training objectives to reduce duplication of effort on the part of Tactics and other divisions. An example of such a situation is the knowledge associated with radar principles, theory, etc. Obviously, the basic officer must receive training in these areas to effectively make use of radar information. This type of knowledge is provided by the Operations Division, however, and thus, it is unnecessary for tactics training to cover the same area. One of the training objectives (No. 28, Appendix A) is to provide the trainee with knowledge concerning the use of radar in the fire control problem. This type of information will not be specifically covered by the Operations Division and, therefore, should be included in the tactics training program.

4.5 The training objectives are based on the fire control systems in operational use by the fleet (e.g., Mk 113 Mod 6). Several of these objectives will be modified and/or changed to meet the demands of the Mk 113 Mod 10, currently in the development stage. This system (Mk 113 Mod 10) is expected to become operational in the mid 1970s. It will utilize a CRT display to increase the information processing capacity of the operator and, generally, to increase the fire control system capabilities of the submarine (e.g., Ray Trace and MATE). New requirements for operator interaction will evolve. (The training needs for the Mk 113 Mod 10 have been considered in the device recommendations (Sections 5.16 and 5.47).)

4.6 The training objectives reflect both operational and theoretical use of the fire control system. The Medical Research Laboratory report (New London Submarine Base, 1967), the Pargo study (1968), discussions with Sub School staff, and independent observations have led to the conclusion that the capabilities of the Mk 113 are often not optimally utilized in TMA operations. For example, the analyzer and attack director were designed to operate as a subteam, within the fire control party, for solving target motion analysis. In reality, most fire control parties treat these devices as independent units, often due to a lack of understanding of the device, its capabilities and limitations, and its intended design functions. Training objectives 16 and 17 (Appendix A) are oriented toward emphasizing the "team" aspects of analyzer-attack director target motion analysis.

4.7 A set of conditions is associated with each training objective in Appendix A. The conditions are intended to qualify and/or substantiate the objective as it pertains to training needs; that is, the conditions specify the general framework within which each objective should be achieved. The conditions were useful in determining the training program design and requirements (Section 4.9).

4.8 Figure 4 is a flow diagram of areas included in the training objectives. It represents the relative order in which the various areas should be covered in training. The four major areas - target motion analysis, weapons, sensors, and command and control - lead into a fifth area - the fire control party. This indicates that the individual and subteam (plotting party) skills and knowledge should be developed before entering the fire control party area. The fire control party training essentially consists of integrating the skills and knowledge developed in the other areas into a total team context. The training objectives are thus oriented to the development of individual skills and knowledge, after which the team skills and knowledge should be developed. Training should proceed from the basic concepts, through highly proficient individual skills to, finally, interactive team skills.

4.9 TRAINING PROGRAM REQUIREMENTS

4.10 Training requirements, in terms of training techniques and devices, were determined from the training objectives and training literature review. These specific training requirements were combined to yield training system requirements

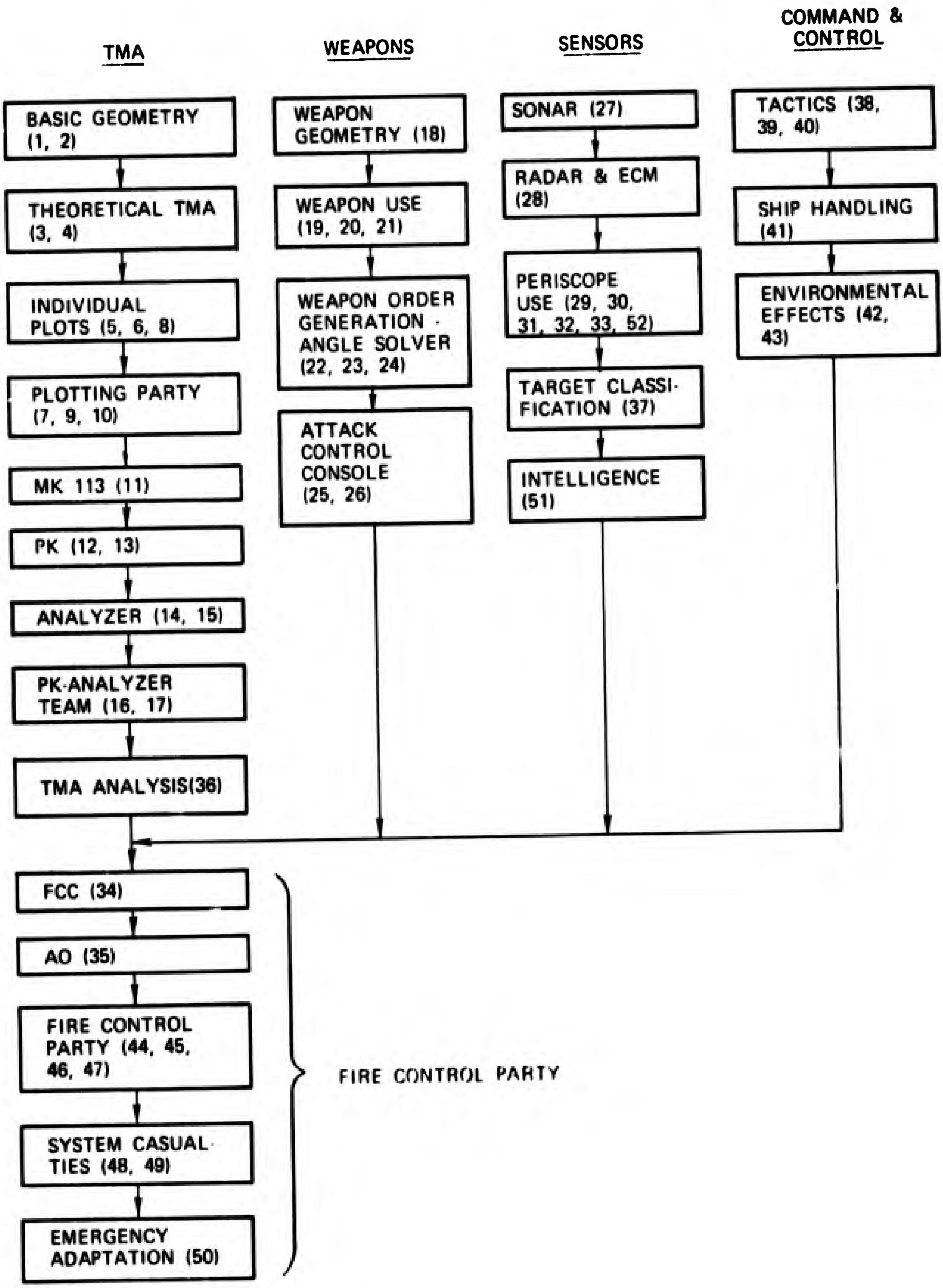



Figure 4. Flow Diagram of Areas Included by the Basic Officer Training Objectives

in terms of general device specifications needed to provide the desired level of training. Essentially, this represents design of the training system based on determined training needs.

4.11 TRAINING REQUIREMENTS. Training requirements were determined from an evaluation of training techniques and devices, with respect to each of the training objectives. Hardware was not considered as a limiting factor at this stage of the study in order to avoid having current equipment determine the requirements. Hardware was considered, however, when its utilization was obviously not cost effective. This situation rarely occurred. An example is computer-assisted instruction (CAI) (in the pure sense) where the computer does the teaching. An interactive CAI teaching program would be of benefit in learning basic TMA knowledge and skills; however, such a program is neither feasible nor practical at this time. Adaptive training on the most finite level (i.e., immediate computer response to each of the trainee's actions) may also be viewed in this regard, since present state of the art has not developed the variables needed for its implementation. However, adaptive training can be effectively implemented on a different scale, that of evaluating trainee performance over a period of time and selecting problem levels to be administered to the trainee.

4.12 In addition, the training methods are somewhat limited by the information available on trainee performance. Specific knowledge of results can be obtained only if performance measures are available to the instructor or training device. Adaptive training cannot be implemented without such measures; instructors are also hampered by lack of such measures. Objective performance measures and standards do not exist for most areas of the fire control party. Instructors, therefore, must base their evaluation of the trainee on their own experiences, which vary. This requires more observation time by the instructor which he could use more effectively in other ways. Adaptive training was considered, based on the thought that performance measures and standards should be developed for the fire control party, regardless of the training technique or device.

4.13 Each of the training objectives was evaluated to determine the appropriateness and level of each training technique. Table 2 is a matrix of training techniques versus training objectives. Table 3 is a matrix of devices versus training objectives. Note that several of the techniques and devices have more than one category (e.g., problem fidelity: time, data, and mental task). An X represents a training technique or device which is desirable in training to meet that specific objective. Differing amounts of fidelity and stress variables may be desired, thus, an L (low), M (medium), or H (high) rating. The boxes left blank indicate that the specific variable is not desired or is inappropriate for the training objective.

4.14 Several training objectives may appear to have conflicting training techniques or devices indicated (for example, No. 1, both individual training and classroom lecture). This may be because: (1) both techniques or devices may be equally

TABLE 2. TRAINING TECHNIQUES VS TRAINING OBJECTIVES

| Objectives | Individual | Team | Problem Fidelity | | | Hardware Fidelity | Feed-back | | KOR* | | Stress | Adap-tive | | Procedural Training | Team Inter-action Trng | Dec. Making Training | Mental Analysis | Group Trng (Class) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Time | Data | Mental Tasks | | Delayed | Immediate | Group | Individual | | Individual | Group | | | | | |
| 1 | X | | | | M | | | | | X | | X | X | | | | X | X |
| 2 | X | | | | M | | | | | X | | X | X | | | X | X | X |
| 3 | | | | | | | | | | | | | | X | | | | X |
| 4 | X | | L | L | H | L | | X | | X | L | X | X | X | | X | X | X |
| 5 | | | | | | | | | | | | | | X | | | | X |
| 6 | X | | M | H | H | M | X | X | | X | L | X | X | X | | X | X | |
| 7 | | | | | | | | | | | | | | X | | | | X |
| 8 | | | | | | | | | | | | | | X | | | | X |
| 9 | | X | M | H | H | M | X | X | X | X | M | | X | X | X | X | X | |
| 10 | | X | M | M | H | M | X | | X | | M | | | | X | X | X | |
| 11 | | | | | | | | | | | | | | X | | | | X |
| 12 | | | | | | | | | | | | | | X | | | | X |
| 13 | X | | M | H | H | M | | X | | X | M | X | X | X | | X | X | |
| 14 | | | | | | | | | | | | | | X | | | | X |
| 15 | X | | M | H | H | M | | X | | X | M | X | X | X | | X | X | |
| 16 | | | | | | | | | | | | | | X | | | | X |
| 17 | | X | M | M | H | M | X | X | X | | M | | X | X | X | X | X | |

X - Desirable training technique or device.
L - Low amount of fidelity and stress variables.
M - Medium amount of fidelity and stress variables.
H - High amount of fidelity and stress variables.
*KOR - Knowledge of Results

TABLE 2. TRAINING TECHNIQUES VS TRAINING OBJECTIVES (Continued)

| Objectives | Individual | Team | Problem Fidelity | | | Hardware Fidelity | Feed-back | | KOR* | | Stress | Adap-tive | | Procedural Training | Team Inter-action Trng | Dec. Making Training | Mental Analysis | Group Trng (Class) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Time | Data | Mental Tasks | | Delayed | Immediate | Group | Individual | | Individual | Group | | | | | |
| 18 | | | | | M | | | | | | | X | X | | | | X | X |
| 19 | | | | | | | | | | | | | | X | | | | X |
| 20 | | | | | | | | | | | | | | X | | | | X |
| 21 | | | | | | | | | | | | | | X | | | | X |
| 22 | X | | L | M | H | L | | X | | X | L | X | X | X | | X | X | |
| 23 | | | | | | | | | | | | | | X | | | | X |
| 24 | X | | M | H | H | M | | X | | X | M | X | X | X | | X | X | |
| 25 | | | | | | | | | | | | | | X | | | | X |
| 26 | X | | M | H | H | M | | X | | X | L | X | X | X | | X | | |
| 27 | | | | | | | | | | | | | | X | | | | X |
| 28 | | | | | | | | | | | | | | X | | | | X |
| 29 | | | | | | | | | | | | | | X | | | | X |
| 30 | | | | | | | | | | | | | | X | | | | X |
| 31 | | | | | | | | | | | | | | X | | | | X |
| 32 | X | | L | H | H | L | | X | | X | L | X | X | X | | X | X | |
| 33 | | X | H | M | M | H | | X | X | X | M | | | X | X | X | | |
| 34 | | | | | | | | | | | | | | X | | | | X |
| 35 | | | | | | | | | | | | | | X | | | | X |
| 36 | X | | L | H | H | L | X | X | | X | L | X | | | | X | X | |
| 37 | X | | L | H | H | L | X | X | | X | L | X | | | | X | X | |
| 38 | | | | | | | | | | | | | | X | | | X | X |
| 39 | | | | | | | | | | | | | | X | | | X | X |

TABLE 2. TRAINING TECHNIQUES VS TRAINING OBJECTIVES (Continued)

| Objectives | Individual | Team | Problem Fidelity | | | Hardware Fidelity | Feed-back | | KOR* | | Stress | Adap-tive | | Procedural Training | Team Inter-action Trng | Dec. Making Training | Mental Analysis | Group Trng (Class) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Time | Data | Mental Tasks | | Delayed | Immediate | Group | Individual | | Individual | Group | | | | | |
| 40 | X | | L | H | H | M | X | X | | X | M | X | | X | | X | X | |
| 41 | | | | | | | | | | | | | | X | | | X | X |
| 42 | X | | | | | | | | | | | | | | | | | X |
| 43 | X | | L | H | H | M | X | X | | X | L | X | | X | | X | X | |
| 44 | | | | | | | | | | | | | | X | | | | X |
| 45 | | X | M | H | H | H | X | X | X | X | M | | | X | X | X | X | |
| 46 | | X | M | M | H | M | X | X | X | | M | | | | X | | | |
| 47 | | | | | | | | | | | | | | | X | X | X | X |
| 48 | | | | | | | | | | | | | | X | | | | X |
| 49 | X | | L | H | H | M | X | X | | X | M | | | X | | X | X | |
| 50 | | X | M | M | H | H | X | X | X | X | M | | | X | X | X | | |
| 51 | | | | | | | | | | | | | | | | | X | X |
| 52 | X | | L | H | H | M | | X | | X | | | | X | | X | X | |

TABLE 3. DEVICES VS TRAINING OBJECTIVES

| Objectives | Classroom | | Text | Audio-Visual | | | Simulators | | |
|---|---|---|---|---|---|---|---|---|---|
| | Lecture | Problem Session (Paper & Pencil Tests) | Textbook | Classroom | Debriefing | Library | Mockup | Mechanical | Computer Controlled |
| 1 | X | X | X | X | | X | | | X |
| 2 | X | X | X | X | | X | | | X |
| 3 | X | | X | X | | X | | | |
| 4 | | X | | | | | | | X |
| 5 | X | | X | X | | X | | | |
| 6 | | | | | | | | X | X |
| 7 | X | | X | X | | X | | | |
| 8 | X | | X | X | | X | | | |
| 9 | | | | | X | | | X | |
| 10 | | | | | | | | X | |
| 11 | X | | X | X | | X | X | | |
| 12 | X | | X | X | | X | X | | |
| 13 | | | | | | | X | X | X |
| 14 | X | | X | X | | X | X | | |
| 15 | | | | | | | X | X | X |
| 16 | X | | X | X | | X | | | |
| 17 | | | | | X | | | X | X |
| 18 | X | X | X | X | | X | | | X |
| 19 | X | | X | X | | X | | | |
| 20 | X | | X | X | | X | | | |
| 21 | X | | X | X | | X | | | |
| 22 | | X | | | | | | | X |
| 23 | X | | X | X | | X | X | | |
| 24 | | | | | | | X | X | X |

TABLE 3. DEVICES VS TRAINING OBJECTIVES (Continued)

| Objectives | Classroom | | Text | Audio-Visual | | | Simulators | | |
|---|---|---|---|---|---|---|---|---|---|
| | Lecture | Problem Session (Paper & Pencil Tests) | Textbook | Classroom | Debriefing | Library | Mockup | Mechanical | Computer Controlled |
| 25 | X | | X | X | | X | X | | |
| 26 | | | | | | | X | X | X |
| 27 | X | X | X | X | | X | X | | |
| 28 | X | | X | X | | X | | | |
| 29 | X | | X | X | | X | | | |
| 30 | X | | X | X | | X | | | |
| 31 | X | X | X | X | | X | | | |
| 32 | | X | | X | | X | | X | |
| 33 | | | | | | | X | X | |
| 34 | X | | X | X | | X | | | |
| 35 | X | | X | X | | X | | | |
| 36 | | X | | | | X | | | X |
| 37 | | X | | | | X | | | X |
| 38 | X | X | X | X | | X | | | |
| 39 | X | X | X | X | | X | | | |
| 40 | | X | | | | | | | X |
| 41 | X | X | X | X | | X | | | |
| 42 | X | X | X | X | | X | | | |
| 43 | | X | | | | | | | X |
| 44 | X | | X | X | | X | | | |
| 45 | | | | | X | | | | X |
| 46 | | | | | X | | | | X |
| 47 | X | | | X | | | | | |
| 48 | X | X | X | X | | X | | | |

TABLE 3. DEVICES VS TRAINING OBJECTIVES (Continued)

| Objectives | Classroom | | Text | Audio-Visual | | | Simulators | | |
|---|---|---|---|---|---|---|---|---|---|
| | Lecture | Problem Session (Paper & Pencil Tests) | Textbook | Classroom | Debriefing | Library | Mockup | Mechanical | Computer Controlled |
| 49 | X | X | X | X | X | X | | X | X |
| 50 | | | | | X | | | X | X |
| 51 | X | X | X | X | | X | | | |
| 52 | | X | | X | | X | | | X |

desirable; (2) one technique or device is preferred but may be impractical to implement at this time; and (3) each objective covers several skill and/or knowledge requirements for which different training techniques and devices may be desired. Often, both procedural and higher order tasks exist within a training objective, thus the apparent conflict in designation.

4.15 In several instances one or more variables (e.g., feedback) may be omitted due to the particular circumstances. For example, paper and pencil tests are desired for training objective No. 1. Obviously, immediate feedback is not feasible for a test of this nature. If a computer-controlled device were used for the training of this objective (e.g., adaptive training), however, immediate feedback would be desirable. In either case, individual knowledge of results (KOR) is appropriate.

4.16 Certain conclusions can be drawn after examining tables 2 and 3.

1. Audio-visual aids are recommended for all classroom lectures and should be made available in the library to trainees.

2. Procedurally oriented skills are involved in most of the training objectives together with higher order skills (e.g., decision making).

3. Adaptive training, at a problem adaptive level, is both desirable and feasible (assuming the necessary measures, etc, will be developed) for several of the training objectives.

4. Textbooks are desirable for acquiring the knowledge required by most of the training objectives.

5. Group training, such as a lecture, is needed for many of the training objectives; however, these may be replaced in the future by computer-assisted instruction.

6. The need exists for both individual and team training devices to train operation of specific hardware.

4.17 These tables relate specific training techniques and devices to the training objectives, thus, device requirements (e.g., lecture and simulator) are determined which meet the training objectives. These device requirements must be combined to develop the overall training system requirements. In addition, the projected future training needs, such as MATE and Ray Trace, must also be considered.

4.18 TRAINING SYSTEM REQUIREMENTS

4.19 Training system requirements consist of recommended devices and their functional specifications, necessary for meeting the training objectives. The training requirements developed in conjunction with the training objectives (tables 2 and 3) yield a set of device requirements. For example, a device which would meet the requirements of training objective no. 4 (as specified in tables 2 and 3) is an individual trainer with low time, data, and hardware fidelity; high mental task fidelity; immediate feedback; individual KOR; low stress levels; group or individual adaptive training; paper and pencil level (basic theory and skills); procedural, decision-making, and mental analysis skills; and computer control. If adaptive training is to be used, it is desirable to have the device computer controlled. An alternative to adaptive training is paper and pencil problems, possibly eliminating immediate feedback.

4.20 The device specified in the above example is a generalized individual trainer, not related to any specific piece of operational hardware. Several other training objectives have similar requirements (i.e., requirements for a generalized training device). In this manner, one training device may fulfill requirements of several training objectives. In addition, the training requirements can often be combined across objectives to yield device specifications which are compatible with seemingly different training requirements; for example, if one trainer could simulate more than one device.

4.21 Device specifications were determined from the training requirements of tables 2 and 3. These devices and their associated functional requirements are listed in table 4. Devices with similar requirements are grouped together, such as the position keeper, angle solver, analyzer, and attack control console. Note that the position keeper (PK) and the angle solver are indicated as separate devices, even though they are both part of the attack director. This was because of the distinct differences in their respective functions; i.e., the PK is used for TMA; the angle solver is used for weapon order generation and torpedo wire guide control. Similar instances can be seen with other devices.

4.22 RECOMMENDED TRAINING SYSTEM. The recommended training system would be composed of both individual and team trainers, in addition to the more conventional training devices (e.g., classroom lecture). Trainees should receive both individual and team training to develop the necessary complex skills. Adaptive training, on both a group and individual level, is desirable; however, such training will largely depend on developing means of measuring the trainee's performance. In any event, the devices should have the capability for eventually being used in adaptive training. Several of the devices should be computer controlled, while others can be mechanically controlled. Computer-controlled devices should have machine scoring capabilities, and have flexible software which easily permits projected modifications. The devices listed in table 4 are not the final device recommendations, but, rather, are the lowest level of devices which will fulfill the system requirements. Several of these devices can be combined without an apparent loss of training effectiveness and at a substantial savings in cost (treated in Section V). The devices specified by the training requirements are:

1. classroom training with audio-visual aids;
2. individual audio-visual aids in the library;
3. paper and pencil problem sessions;

TABLE 4. DESIRED TRAINING DEVICES AND FUNCTIONAL REQUIREMENTS

| Devices | Individual | Team | Problem Fidelity | | | Hardware Fidelity | Feed-back | | KOR | | Stress | Adap-tive | | Group | Audio-Visual | Simulator | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Time | Data | Mental Task | | Immediate | Delayed | Group | Individual | | Individual | Group | | | Mockup | Mechanical | Computer Controlled |
| Classroom | | | | | | | | | | | | | | X | X | | | |
| Paper & Pencil Problems | X | | L | M | H | | | X | | X | | | X | X | | | | |
| Library | X | | | | | | | | | | | | | | X | | | |
| Textbook | X | | | | | | | | | | | | | | | | | |
| Generalized Trainer | X | | L | H | H | M | X | X | | X | M | X | | | | | | X |
| Position Keeper | X | | M | H | H | M | X | X | | X | M | X | | | X | | | X |
| Angle Solver | X | | M | H | H | M | X | X | | X | M | X | | | X | | | X |
| Analyzer | X | | M | H | H | M | X | X | | X | M | X | | | X | | | X |
| Attack Control Console | X | | M | H | H | M | X | X | | X | M | X | | | X | | | X |
| Periscope | X | | L | H | H | L | X | | | X | L | X | X | X | X | | X | |
| Periscope | | X | H | M | M | H | X | | X | X | M | | | | | | X | |

X - Desirable training technique or device.
L - Low amount of fidelity and stress variables.
M - Medium amount of fidelity and stress variables.
H - High amount of fidelity and stress variables.

TABLE 4. DESIRED TRAINING DEVICES AND FUNCTIONAL REQUIREMENTS (Continued)

| Devices | Individual | Team | Problem Fidelity | | | Hardware Fidelity | Feed-back | | KOR | | Stress | Adap-tive | | Group | Audio-Visual | Simulator | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Time | Data | Mental Task | | Immediate | Delayed | Group | Individual | | Individual | Group | | | Mockup | Mechanical | Computer Controlled |
| Plotting Party | | X | M | H | H | M | X | X | X | X | M | | X | | | | | X |
| PK-Analyzer | | X | M | M | H | M | X | X | X | | X | | X | | X | | | X |
| Fire Control Party | | X | M | H | H | H | X | X | X | X | M | | | | X | | | X |
| Plotting Party | | X | M | H | H | H | X | X | X | X | M | | X | | | | X | |
| Mk 19 Strip Plot | X | | M | H | H | M | X | X | | X | M | X | | | | | X | |
| Time Bearing Plot | X | | M | H | H | M | X | X | | X | M | X | | | | | X | |
| Relative Motion Plot | X | | M | H | H | M | X | X | | X | M | X | | | | | X | |
| Position Keeper | X | | | | | L | | | | | | | | X | | X | | |
| Analyzer | X | | | | | L | | | | | | | | X | | X | | |
| Angle Solver | X | | | | | L | | | | | | | | X | | X | | |
| Attack Control Console | X | | | | | L | | | | | | | | X | | X | | |
| Weapon Control Console | X | | M | H | H | M | X | X | | X | X | X | | | X | | | X |

4. textbooks;

5. a generalized individual trainer to train concepts and knowledge;

6. individual trainers (computer controlled) for the PK, angle solver, analyzer, and attack control console.

7. two periscope trainers, one for training the visual knowledge and skills, and one for training the mechanics of operation in accordance with tactical procedures;

8. individual trainers for the strip plot, time bearing plot, and relative motion plots;

9. team trainers (computer controlled) for the plotting party, the PK-analyzer team, and the fire control party (a mechanical plotting party trainer may be substituted for the computer-controlled device); and

10. mockups for the PK, angle solver, analyzer, and attack control console.

4.23 INDIVIDUAL TRAINERS. As seen from the list in Section 4.22, several individual trainers are needed to train specific skills. Also, due to the increasing complexity of fire control problems, system hardware, methods of TMA problem solving, weapons, and functions required of each individual operator, extensive individual training must be given. Findings of the MRL study, Pargo study, and Sub School staff, and training session observations by the present researchers concur in the need for greater individual operator proficiency. Operators need to develop a greater understanding of the interrelationships between target and ownship parameters and how to use this knowledge in solving fire control problems on the respective devices. Operators must develop a high level of proficiency on each of the operational devices to facilitate real-world TMA (i.e., become proficient in team problem solving under adverse conditions such as stress, equipment casualties). For example, the Pargo study has shown that operators become confused when faced with an unexpected malfunction such as a sequence light failing to light.

4.24 The individual trainers should adequately train all individual skills and knowledge required of the operator. Of most importance are the mental skills and knowledge rather than the motor skills. For this reason, it is not necessary to have high hardware fidelity trainers, provided the mental tasks can be of high fidelity. Also, the devices should be sufficiently flexible to vary the problem difficulty in an adaptive manner, and provide immediate individual KOR and some amount of stress in the latter training stages. Ideally, the devices should provide machine scoring, after objective measures, etc, have been developed. At least eight different individual trainers are needed, each of which meets these specifications.

4.25 TEAM TRAINERS. Team trainers are needed for the plotting party, position keeper-analyzer team, and for the total fire control party. The purpose of each team trainer is to develop team functioning on the part of the individual operators, that is, to mold the individuals into a coherent unit, working together to achieve the same ultimate goals. Team training should be undertaken only after the trainees have mastered their individual skills and knowledge; that way, individual deficiencies would not interfere with team development. In addition, the team skills needed in complex problem solving utilize previously developed individual skills.

4.26 The team trainers need not have high fidelity hardware in all cases. The plotting party and the position keeper analyzer team trainers need not be of high fidelity; however, they must present high fidelity data to the trainee and require the trainee to perform high fidelity mental tasks. Several training objectives do require high fidelity hardware in the fire control party trainer because of the nature of the complex team tasks. The fire control party (total team) trainer should be of high hardware fidelity to satisfy requirements not covered by devices of lesser fidelity, such as experience in operating the actual equipment in an encounter, firing weapons, etc. In addition, the trainees should receive training and/or experience in the operational system; only in this way can the complex skills be fully developed. An actual submarine for such training is most desirable and a certain amount of onboard training does occur; however, such usage of a submarine is both costly and potentially hazardous. Thus, a hardware, high fidelity simulator is the most desirable alternative.

4.27 High fidelity team trainers, utilizing sophisticated hardware, must be computer controlled to provide the proper hardware and environmental responses. Simpler team simulators, however, such as for the plotting party, need not have a highly sophisticated control unit; only the data normally provided need be controlled by an external device. Where a computer control unit is available, it is usually desirable to develop automatic evaluation by the computer; of course, this is not always possible. It does not appear possible at the present time to implement automatic evaluation of the fire control party. It should be instituted on the individual trainers, however, and studies made of its application in the team situation.

4.28 Two separate periscope trainers are required. The skills and knowledge needed for periscope sighting, obtaining ranges, etc, can be broken down into two distinct part-tasks: (1) the visual skills and knowledge, such as estimating ship speed by bow wave, estimating masthead height, and identifying ship nationality and class, etc; and (2) the mechanical skills of periscope raising, information relay, etc. Training time is much longer for the visual skills and knowledge than for the mechanical skills; logically their training can and should be separated.

4.29 The visual training device should present high fidelity visual data and require the trainee to perform high fidelity mental tasks. The hardware may be of low fidelity. Conversely, the mechanical training device need not present high fidelity visual information, but the device appearance and operation should be of high fidelity.

4.30 This list of devices (table 4) represents the system training requirements for adequately achieving the objectives of basic officer training. It illustrates the device needs of the training program, without regard to existing or recommended devices. These needs must be reconciled with the existing facilities to determine the extent to which present training devices meet the requirements. Furthermore, factors such as existing device modifications, the combining of several device requirements into one device, future and present flexibility, cost effectiveness, etc, must be considered in determining device recommendations. These factors are considered in Section V, where specific devices and device modifications are recommended.

# SECTION V

# DISCUSSION

5.1 Training objectives were developed from the individual operator skills and knowledge and with respect to the desired trainee (basic officer) output characteristics. Training techniques and devices for attaining these objectives were recommended. These combined techniques and devices represent a theoretical training system from which hardware recommendations must come. This section discusses the ability of existing training devices to meet the system requirements, and recommends modifications to existing devices and new devices to meet the unfulfilled requirements.

## 5.2 USE OF PRESENT TRAINING FACILITIES

5.3 The devices specified in table 4 fully meet the requirements of the training objectives. These devices and specifications were compared with existing training facilities at the New London Submarine Base to determine to what extent these facilities could fulfill training system requirements. (Section 3.40 summarizes the existing facilities.) It was determined that many of the hardware and software requirements can be met by existing devices.

5.4 Classroom and library facilities are in existence but they make limited use of audio-visual aids. It would be desirable to present tape recorder-slide projector lectures which cover the majority of classroom teaching. Copies of these lectures could then be made available to individuals in the library. The material presently given in classroom lectures could be reorganized into this format. (Audio-visual aids will be discussed in greater detail in Section 5.16.)

5.5 Paper and pencil problems currently exist for much of the course work and therefore need not be reorganized. Updating and modification should occur on a continuing basis, however.

5.6 Textbooks (manuals) exist for much of the basics of tactics training (target-own ship geometry); however, the material is somewhat outdated with respect to modern weapons' systems and tactics. Submarine Base personnel have written a Mk 113 operators manual, but they lack a modern tactics manual. The current tactics manual is oriented primarily towards the plots and older fire control systems.

5.7 Individual plot trainers exist, with the exception of a Mk 19 Strip Plot, and are of sufficient hardware fidelity. They are presently used for both individual and team training. The plots are inexpensive to operate and are seldom used for other than basic officer training. A Mk 19 Strip Plot does not exist as an individual training device; however, an older form of the strip plot is in existence (Mk 7 Strip Plot), requiring essentially the same skills and knowledge as the Mk 19.

5.8 Data generated for the plots originates from the position keeper section of an old target data computer. This data source is adequate, except for the lack of variably degradable data; that is, the generated data is perfect, unlike real-world data. (Supposedly the old hardware supplies its own data degradation.) It would be desirable to add a mechanical, or an electronic, degrading source so that the skills for plotting faired bearings, etc, can be adequately developed.

5.9 Several Mk 113 fire control party simulators are in use at the Submarine Base (Section 3.40). Each is of sufficient hardware fidelity to meet the training needs of the fire control team. In their present operating form, however, the simulators lack the capability of introducing randomly degradable sonar information and equipment malfunctions. This capability to insert degradable sonar information does exist on one fire control party simulator, the 21A37/4; however, the program degrades sonar as a sine function. After several sessions, the operator typically adapts to this periodic degradation.

5.10 Two of the fire control party simulators generate history tracks (own ship, target, and weapon position) on a screen throughout the problem as a function of time. The history tracks provide a static display (i.e., a picture) to the trainees following termination of the problem (i.e., used for debriefing purposes). This is in contrast to the dynamic play-back capability of several other simulators, in which the actual development of history tracks can be replayed (i.e., problem development can be viewed through a play-back capability). The static playback capability appears adequate for basic officer team training, although a dynamic playback display with other data sources may prove of value in advanced training. During team training of basic officers, the emphasis should be on the development of team interaction and functioning. Advanced training, which is often more concerned with target-own ship tactics, maneuvering, etc, may benefit from dynamic playback.

5.11 Machine scoring is not necessary for basic officer team training in the fire control party simulator. In addition, it would be extremely difficult to administer because of problems in obtaining adequate measurements of team performance; i.e., hit or miss is the wrong criterion of trainee performance.

5.12 Equipment casualties and malfunctions can be introduced to a limited extent in training, although this is seldom done. It would be desirable to adapt the simulator software so as to permit the introduction of real-time equipment casualties and malfunctions. Aside from the obvious value in training basic officers to cope with casualties and malfunctions, it offers a means of introducing stress into the environment.

5.13 The periscope trainers presently used are of high hardware fidelity and adequate visual data fidelity. They are sufficient for training basic officers in the mechanics of periscope operation, but their usefulness in training visual skills such as masthead height estimation is somewhat limited due to the short periods of actual usage. During the training period when the trainee is at the periscope station, the length of time he actually looks through the periscope may be only a small percentage of the total training time available to him. Therefore, the visual skills must be acquired through repetitive practice. An individual device on which to practice is needed which simulates the visual information received. This type of device should be available for practice on a daily basis.

5.14 As pointed out in Section IV, the need exists for several specific individual trainers, other than the plots,to simulate the position keeper and angle solver sections of the Mk 75 attack director, the Mk 51 analyzer, and the Mk 50 attack control console. Such trainers do not exist. Present training is obtained on the fire control party simulator on which a group of about 10 trainees are simultaneously trained in both individual and team skills. Due to the number of trainees and the fact that the three fire control party simulators must also be used for SSBN and SSN refresher training, and PXO and PCO advanced tactics training, they cannot possibly be used for basic officer individual training too. In addition to the individual trainers mentioned, the need exists for an individual trainer to teach general skills and knowledge (e.g., decision making) not associated with a particular operational device. Such a trainer does not presently exist.

5.15 In summary, the existing facilities lack:

1. audio-visual aids in the classroom and library,
2. an up-to-date tactics manual,
3. degradable sonar data for the plots and fire control party simulators,
4. a periscope visual skills training device, and
5. several individual trainers for training particular skills.

The following sections recommend hardware and software for meeting these needs and discuss the flexibility of the recommended devices for meeting present and future training requirements.

5.16 NEW DEVICE NEEDS AND EXISTING DEVICE MODIFICATIONS

5.17 The training system requirements were evaluated with respect to existing facilities to determine training device needs. These training device needs were then evaluated. A decision was made on whether these needs could best be served by modifying existing devices, or by combining related requirements and recommending new cost-effective devices. Table 5 lists the devices recommended to meet the training requirements. The table consists of existing devices; existing devices

TABLE 5. RECOMMENDED TRAINING DEVICES AND DEVICE REQUIREMENTS

| Training Device | | Device Parameters |
|---|---|---|
| Classroom (m) | | Group lecture |
| | (m) | Audio-visual aids (slide projector, tape recorder) |
| Library (m) | (m) | Individual audio-visual aids (individual viewer, tape recorder) |
| Paper & Pencil Problems | | Individual -- delayed feedback |
| Textbook (nd) | (nd) | Modern tactics manual |
| Generalized Individual Trainer (nd) | | Low-medium time fidelity<br>Low-high data fidelity<br>Low-high mental task fidelity<br>Medium hardware fidelity<br>Immediate and delayed feedback<br>Individual KOR<br>Low-medium stress<br>Individual adaptive<br>Visual playback capability<br>Computer controlled<br>Must be able to simulate with medium fidelity:<br>Position keeper<br>Angle solver<br>Analyzer<br>Firing panel on attack control console<br>Utilizing two such devices, must be able to act as a PK-analyzer team simulator<br>Must be able to simulate forseeable future fire control devices for individual training |
| Plotting Trainer (m) | | Individual and team trainer<br>Low-medium time fidelity |
| | (m) | Low-high data fidelity |
| | | Low-high mental task fidelity<br>Medium hardware fidelity<br>Immediate and delayed feedback<br>Individual and group KOR<br>Low-medium stress<br>Individual and group adaptive |
| | (m) | Computer-inputed data |
| | | Must be able to simulate with medium fidelity:<br>Mk 19 Strip Plot<br>Time/Bearing Plot<br>Relative Motion Plot |

TABLE 5. RECOMMENDED TRAINING DEVICES AND DEVICE REQUIREMENTS (Continued)

| Training Device | | Device Parameters |
|---|---|---|
| Plotting Trainer (m) (cont'd) | | Utilizing several such devices, must be able to act as a plotting party simulator |
| Fire Control Party (m) | | Team trainer |
| | | Low-medium time fidelity |
| | (m) | Low-high data fidelity |
| | | Low-high mental task fidelity |
| | (m) | High hardware fidelity: simulate each device and their interaction, immediate and delayed feedback |
| | | Individual and group KOR |
| | | Low-medium stress |
| | | Visual feedback capabilities |
| | | Computer controlled |
| Periscope-Visual (nd) | | Individual or in group |
| | | Low time fidelity |
| | | High data fidelity |
| | | High mental task fidelity |
| | | Low hardware fidelity |
| | | Immediate feedback |
| | | Individual KOR |
| | | Low stress |
| | | Individual and group adaptive |
| | | Visual aid |
| | | Mechanically controlled |
| Periscope-Mechanical | | Team trainer |
| | | High time fidelity |
| | | Medium data fidelity |
| | | Medium mental task fidelity |
| | | High hardware fidelity |
| | | Immediate feedback |
| | | Individual and group KOR |
| | | Low-medium stress |
| | | Mechanically controlled |

m -- modifications recommended to the existing device
nd -- new device

with recommended modifications, denoted by an "m" next to the device name and recommended modification; and recommended new devices, denoted by an "nd" next to the device. The respective device parameters are also listed in the table.

5.18 Three new devices are recommended:

1. A modern tactics manual.
2. A generalized individual trainer.
3. A visual periscope simulator.

Mofifications to four existing devices are recommended:

1. Audio-visual aids in the classroom.
2. Individual audio-visual aids in the library.
3. High fidelity sonar data and equipment casualties and malfunctions for the fire control party simulator.

5.19 AUDIO-VISUAL AIDS IN THE CLASSROOM. Classroom lectures should be given in conjunction with audio-visual aids. Visual slides could be made up and presented together with a tape-recorded lecture, thereby providing the trainee with visual as well as auditory information. A ten-minute tape recorder-slide presentation could be given alternately with a question and answer discussion period. Thus, the material covered in the lecture would be standardized and optimally presented every time. It would not be subject to teacher variance, time shortage, etc. The material to be presented would be determined in advance, thereby ensuring adequate coverage of all topics. Clarification and discussion of the presented material, answering questions, etc, would immediately follow the ten-minute lecture, providing for student-instructor interaction.

5.20 The tape recorder can be of standard design, preferably one using tape cartridges. The slide projector should be automatic and should operate from a tape-recorded cue. These systems exist today and are relatively inexpensive. A slide projector system is preferred over a movie system because of the relative ease of making and editing the slide information.

5.21 LIBRARY AUDIO-VISUAL AIDS. A copy of each slide-tape-recorded lecture should be available in the library to individuals. An automatic slide viewer connected to a small tape recorder and equipped with earphones would suffice. Trainees would be able to review particular lectures to clarify confusing points, view lectures they may have missed, or preview future material. Eventually, a library of such lectures could be developed. Such a facility would allow students of higher ability to move at a faster pace than the majority. It could also be a source of extra information not covered in class. The cost of this slide-tape recorder device is also relatively inexpensive.

5.22 TEXTBOOK. The present tactics manual is based on older fire control systems and is not adequate for present needs. A study should be undertaken to rewrite the present tactics manual in accordance with theoretical and actual usage of the Mk 113 fire control system, associated sensors, and weapons. This rewrite should also consider the Mk 113 Mod 10 system under development and the tactics changes inherent in the system. (Section IV described the need for a modern tactics manual based on the Mk 113 fire control system.)

5.23 FIRE CONTROL PARTY SIMULATOR. High fidelity, degradable, sonar information is needed on the Mk 113 fire control party simulators. Presently supplied sonar information is either perfect or degraded by a sine function, neither method being satisfactory for a high fidelity simulator. Real-world sonar information is degraded by such factors as delta bias errors and environmental conditions. In the training situation, the fire control party operators are accustomed to working with perfect data which obviously does not exist in the real world. A provision should be made, therefore, for introducing realistically varying data into the sonar information. This variance should be random, its parameters specified by setting a signal-to-noise ratio (S/N) and delta bias error; that is, the delta bias error should be a function of relative bearing, similar to that found on operational submarines. The amount of variance about the delta bias should be specified by the instructor and manually entered into the problem.

5.24 The software for changing the sonar information should be based on a random distribution about a specified parameter (i.e., S/N Gaussian distribution about a delta bias error). Thus, the instructor should have two controls: one for determining the amount of delta bias error, the other for determining the variance of random points about the delta bias error (i.e., the S/N ratio). By the time trainees enter team training, they should have developed individual skill proficiency and be adept at handling less-than-perfect sonar information.

5.25 System casualties and/or malfunctions occur occasionally in the operational fire control system. Trainees should be trained to react correctly and to bypass or rectify these problems. On fire control party trainers, however, the system hardware usually functions perfectly during training exercises. Thus, the trainees are not receiving proper training. Malfunctions and/or casualties should be introduced during problems; for example, a monitor light on the attack control console could fail, or weapon orders could malfunction. In this way trainees would be trained to expect and cope with unanticipated problems. Malfunctions and casualties should be under the control of the instructor; appropriate modifications to existing trainer software should be made to allow for this type of control.

5.26 PLOTTING TRAINER. Realistic (degraded) sonar information should be inserted into the plot training sessions - both individual and team. The rationale for such information is similar to that presented for the fire control party simulators. The early individual training plotting sessions should use highly accurate sonar data to facilitate the learning of plotting skills and knowledge. As the trainee's proficiency grows, degradable data should be introduced. Only through the use of such degradable data can trainees learn to plot faired bearings and work with less-than-perfect information.

5.27 Degradable bearings should be supplied only to the sonar readouts used by the plotting party. The strip plotter should not receive bearing information automatically at this time, as is normally the case in the operational situation. The strip plot does not use degraded information; instead, it uses faired bearings derived from the time/bearing plot. Thus, individual training with degraded bearing information should be given in the time/bearing and relative motion plotting exercises.

5.28 The degraded sonar information should be derived by computer and sent to the sonar readouts adjacent to the plots. The parameters of degradation should be determined in a manner similar to that specified in the fire control party sonar degradation recommendation (i.e., based on delta bias and S/N, Section 5.23). The sonar readouts can be driven by the central processing unit of the recommended generalized individual trainer.

5.29 PERISCOPE VISUAL TRAINER. The skills and knowledge necessary for periscope training consist of: (1) visually and mentally analyzing and evaluating what is seen, and (2) mechanical skills and knowledge involved in raising and lowering the scope. The visual and mental analysis area is by far the most important and complex. Present training in this area is limited by the training requirements of other trainee groups. A trainer is needed, therefore, which will permit the acquiring of visual skills and knowledge alone.

5.30 An individual training device, similar to a slide viewer, is recommended for this purpose. The trainee would practice periscope viewing, classification, ranging, etc, by looking through the viewer's single eyepiece. A library of slides (i.e., photographs, illustrations and silhouettes) could be developed, illustrating the various ship classes, ranges, etc. Through daily practice, the trainee would develop viewing skills and knowledge. For example, a group of such devices could be used in the classroom for 15 minutes every morning. The viewers could all be remotely controlled by the instructor; thus, problem sessions could be run with a group of students, each student looking through his own device. A specific problem might be to estimate masthead height, identify the ship's nationality, or estimate speed from bow wave After all students have indicated their answers, the instructor could immediately indicate the correct answer. A discussion period could then follow.

5.31 GENERALIZED INDIVIDUAL TRAINER.

5.32 Specifications. The present facilities that do not meet training system requirements were studied. Designing a new device to meet each of these requirements was considered both unnecessary and costly; therefore, it was decided to study combining several device requirements to arrive at one device. This approach was most applicable to the individual training device requirements since the specifications were identical. The hardware appearance of the needed devices was different, although their training demands were identical.

5.33 Since high hardware fidelity is unnecessary but problem fidelity is, a device presenting high fidelity information and requiring high fidelity mental tasks would meet the training requirements. The device should also closely resemble the operational hardware and require similar but not necessarily identical operator procedures and tasks. The generalized individual trainer should meet the specifications of each of the individual trainers, in this case, the position keeper, angle solver, analyzer, and attack control console. In addition, it should meet the specifications for the projected individual training needs.

5.34 Description. A generalized individual trainer was designed to meet the specifications for the individual position keeper, angle solver, analyzer, and attack control console. The design was oriented primarily toward problem fidelity, and, to a lesser extent, toward hardware fidelity. Also under consideration in the design of this device were projected individual training device needs centered around the Mk 113 Mod 10 fire control console currently under development. The Mk 81 Weapon Control Console will utilize a CRT display for target motion analysis and other operator functions. The generalized individual trainer is compatible with these projected training needs. (See Section 5.47 for training device flexibility.) In addition, the device under consideration can fulfill the need for a generalized trainer to teach basic concepts; two such devices placed side by side could function as an analyzer-position keeper team trainer.

5.35 The generalized individual trainer consists of several identical consoles, each independently computer controlled. Each console acts as an individual trainer, manned by one trainee. A typical console (figure 5) consists of a CRT display, several input knobs, a light pen, and a keyboard. The CRT displays the information normally found on the operational device in a format similar to that of the operational device. (Figure 6 shows a typical display on the operational device.) The display is dynamic and updated in real time by computer. The display dynamics are easily programmed, and, thus, can be similar to those of the operational device. The lower portion of the CRT is reserved for additional displays, possibly for training purposes; for information normally obtained from other sources in the fire control party, such as an assumed target speed from sonar; or for other pertinent training information.

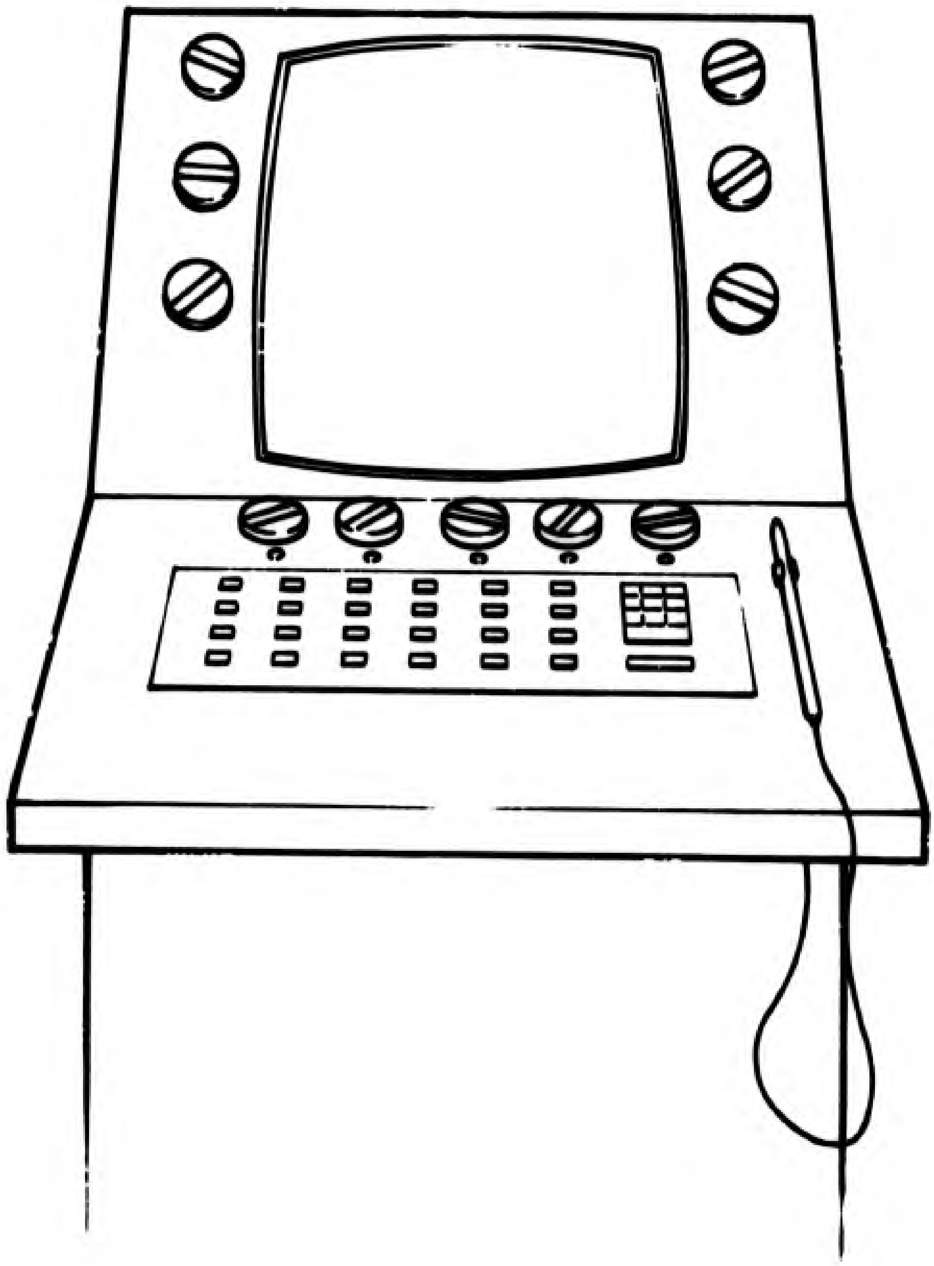


Figure 5. Generalized Individual Trainer Console

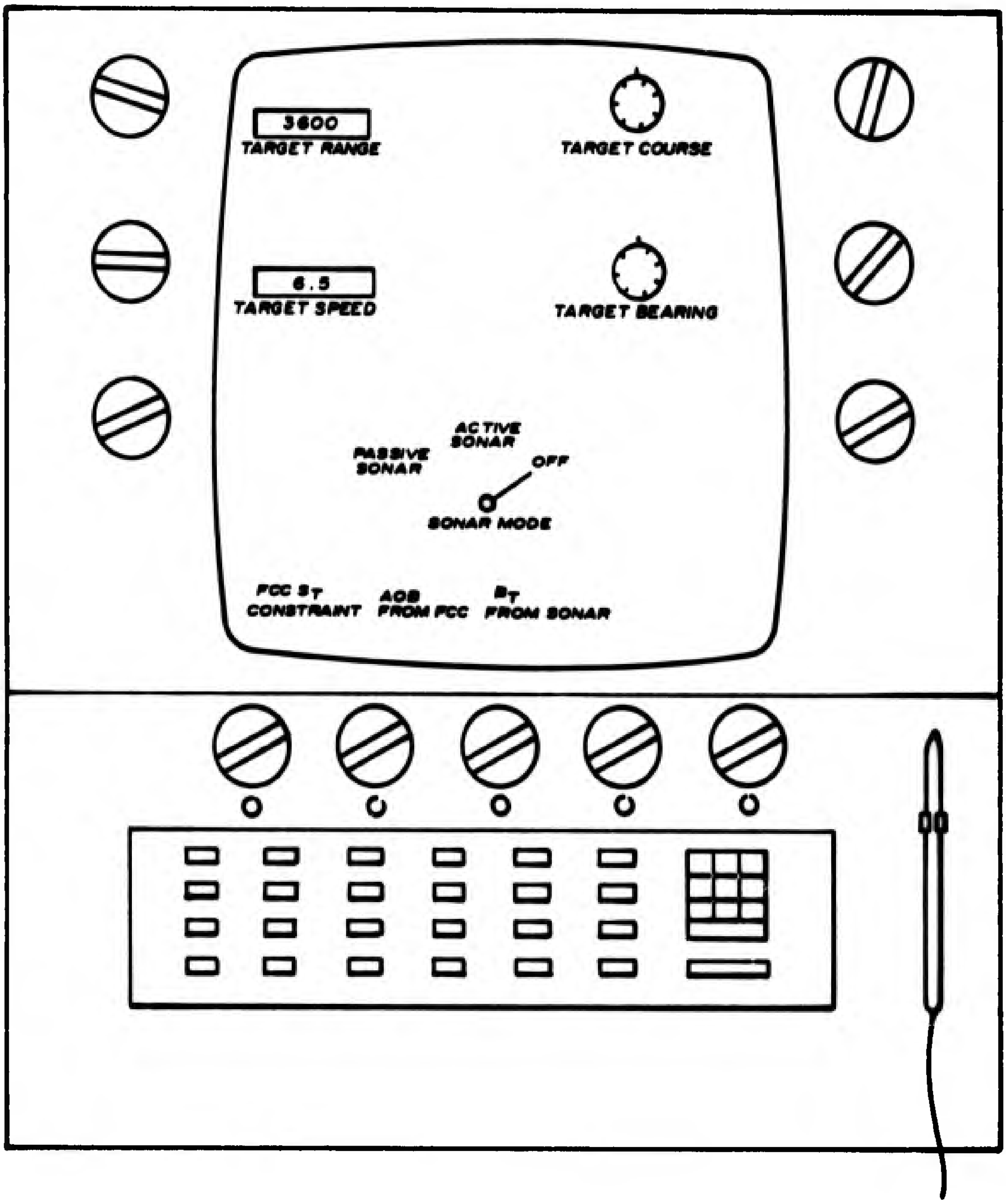



Figure 6. Hypothetical Display on Generalized Individual Trainer Console

5.36 Inputs to the device would be obtained in several different ways: knobs, pushbuttons, or light pen. The three knob locations on each side of the CRT are for the position keeper, angle solver, and analyzer. Since the greatest amount of continuous man-machine interaction takes place on the position keeper during iterative TMA problem solving, the knob locations (for the position keeper) are identical to those on the operational device. The knobs on the operational analyzer are normally located directly under each of the two input and four output readouts. Some small amount of adaptation will be necessary for the analyzer, however, since on the trainer these knobs were placed to the left and right of the readouts. Operator use of the knobs is a relatively minor factor; the actual knob locations can be learned on a fire control party trainer or by studying photographs. Of primary importance is the mental processing and problem solving tasks. A similar rationale was used when laying out the angle solver and attack control console knobs. The row of knobs below the CRT serves the angle solver and MATE simulations; these can be covered when not in use for a particular simulation.

5.37 The light pen is useful in requesting information from the display, or for performing functions found on operational devices for which switches do not exist. An example is the position keeper display (figure 6). The position keeper operator may request target speed constraint information from the Fire Control Coordinator, and may or may not receive such information, depending on the problem circumstances. A channel for display of target speed constraint information (from the fire control coordinator) should be made available on the lower portion of the CRT. For example, instead of verbally requesting the data, the operator would point the light pen at the words, FCC $S_T$ CONSTRAINT. If such information is available at that time, it would be displayed for a short time in that location. If the information were not available, an appropriate response would be displayed. The operator may decide to quiz the displayed information with the light pen; an appropriate information quality such as GOOD could be displayed. Thus, the operator is provided with his requested information and some indication of its quality. This is an example of the kind of operator-trainer interaction that can take place. Obviously, the amount, type, and format of available information on the display would greatly aid the learning process.

5.38 The keyboard could function similar to the light pen. Overlays could be put on the keyboard for different devices to specify different keyboard functions.

5.39 The trainee would interact with the trainer much the same as he would with the operational device. The trainer would respond in the same manner as would the operational device; therefore, the trainee would perform the same as he would on the operational device. The trainee may push a button instead of turning a switch, but this is a minor variation.

5.40 <u>Device Capabilities</u>. One of the primary advantages of a generalized trainer is that it does not have to simulate the operational device. The display and input sources are under control of the computer at all times. The amount and type of information displayed and device functioning can be designed in accordance with training techniques. For example, in the earlier learning stages, it may be desirable to instruct the trainee in the use of one specific type of plot-derived information, i.e., iterative solving on the PK. The CRT can display this information source along with the standard PK display and no other information. In this way, the type of information to utilize in this particular problem is obvious to the trainee. Later in training it may be advantageous to present various types of extraneous information, forcing the operator to select the most appropriate source. Other times it may be desirable to present a dynamic, graphic, own ship-target geometrical presentation, along with the position keeper display, to illustrate how constraint changes affect the PK solution. The CRT is also useful in providing immediate feedback or a graphic playback of the problem following its termination, etc.

5.41 This generalized trainer is capable of providing automatic machine scoring; adaptive individual training in relation to the skills necessary for operation of a specific operational device (e.g., the position keeper); and computer-assisted instruction on basic skills and knowledge (e.g., target-own ship geometry and solving for specific parameters). Such programs are limited by computer programming techniques and training situation variables such as problems designed to train specific skills and objective measures of performance. Although computer-assisted instruction programming techniques (trainee-machine interactive programs) are not yet adequately developed, adaptive programming techniques are developed and are relatively easy to implement. As pointed out earlier, however, objective performance measures and performance standards have not yet been developed for most of the fire control party skills and knowledge. This type of study must be performed before automatic machine scoring can be implemented. In addition, adaptive variables, etc, must be determined before adaptive training can be implemented.

5.42 The value of this generalized training device, in addition to the capabilities just discussed, is its ability to operate relatively independent of the instructor. The instructor's tasks are that of monitoring and making final evaluations based on the machine scoring. If the performance measures, etc, are determined and proper training problems are designed, then one instructor should be able to handle ten individual consoles simultaneously. If, in addition, the adaptive variables, etc, can be determined and adaptive problems designed, each trainee can receive and be working at a different level of training. This is the optimum form of training: allowing the individual to progress at his own rate, depending on his demonstrated performance. Essentially, each trainee is receiving individual tutoring. The instructor's tasks remain the same as for non-adaptive training. (See Section 5.47 for device flexibility.)

5.43 Device Feasibility. The feasibility of developing and using this device is limited only by the lack of objective performance measurements. The hardware needed for such a device is available "off the shelf." Total hardware cost for ten individual terminals and associated computer facilities is estimated to be about $250,000 (Appendix B). Software cost (programming) for the position keeper, angle solver, analyzer, and attack control console displays, problem computations, input-output, etc, is estimated to be the same as for the hardware, about $250,000. In comparison, the cost for a lesser number of operational device simulators would be much greater since they wouldn't have the training flexibility of the generalized trainer.

5.44 SUMMARY OF DEVICE RECOMMENDATIONS. In summary, then, a generalized individual trainer is recommended to meet individual trainer requirements, other than for plots. Two of these consoles can be used as the position keeper-analyzer team trainer. The consoles should be individually computer controlled, with capability for machine scoring and adaptive training. Each console should have a CRT for simulating the operational device display and associated knobs, light pen, and keyboard for operator inputs.

5.45 These recommended training devices and modifications, together with existing training facilities, fulfill the training requirements. Table 6 lists the recommended training devices in relation to the basic officer training objectives. The needs of each training objective are adequately covered by these devices. In addition, the training requirements specified in tables 2 and 3 can be met by the use of these devices.

5.46. After the objective performance measures and standards are developed, problems must be developed for use on the individual generalized trainer in a format suitable for the position keeper and other devices. Concurrent with the development of performance measures, automatic scoring techniques should be developed for use on the device. The scoring techniques might consist of a time-error measure and a final cumulative score. Percentage range error over time may be found to be a good measure of iterative TMA proficiency on the position keeper. The computer should then be programmed to save such a record at discrete intervals, for example, every 30 seconds. Without adequate performance measures, it is virtually impossible to devise scoring techniques.

5.47 When these have been determined, individual training may proceed on a problem-adaptive basis; i.e., the computer can evaluate performance and select a problem of appropriate difficulty. Eventually, a real-time adaptive program may be developed and used with the generalized individual trainer.

5.48 SYSTEM FLEXIBILITY

5.49 The recommended training system is capable of meeting present and projected basic officer training needs. The exception to this statement is the fire control party simulator which will eventually be modified to meet future operational display

TABLE 6. RECOMMENDED TRAINING DEVICES VS BASIC OFFICER TRAINING OBJECTIVES

| Training Objectives | Classroom | Library | Paper & Pen-cil Problems | Textbook | Individual Trainer (General and Specific) | Plotting Trainer | Fire Control Party | Periscope-Visual | Periscope-Mechanics |
|---|---|---|---|---|---|---|---|---|---|
| 1 | X | X | X | X | X | | | | |
| 2 | X | X | X | X | X | | | | |
| 3 | X | X | | X | | | | | |
| 4 | | | X | | X | | | | |
| 5 | X | X | | X | | | | | |
| 6 | | | | | | X | | | |
| 7 | X | X | | X | | | | | |
| 8 | X | X | | X | | | | | |
| 9 | | | | | | X | | | |
| 10 | | | | | | X | | | |
| 11 | X | X | | X | | X | | | |
| 12 | X | X | | X | | | | | |
| 13 | | | | | X | | | | |
| 14 | X | X | | X | | | | | |
| 15 | | | | | X | | | | |
| 16 | X | X | | X | | | | | |
| 17 | | | | | X | | X | | |
| 18 | X | X | X | X | X | | | | |
| 19 | X | X | | X | | | | | |
| 20 | X | X | | X | | | | | |
| 21 | X | X | | X | | | | | |
| 22 | | | X | | X | | | | |
| 23 | X | X | | X | X | | | | |

TABLE 6. RECOMMENDED TRAINING DEVICES VS BASIC OFFICER TRAINING OBJECTIVES (Continued)

| Training Objectives | Classroom | Library | Paper & Pen-cil Problems | Textbook | Individual Trainer (General and Specific) | Plotting Trainer | Fire Control Party | Periscope-Visual | Periscope-Mechanics |
|---|---|---|---|---|---|---|---|---|---|
| 24 | | | | | X | | | | |
| 25 | X | X | | X | | | | | |
| 26 | | | | | X | | | | |
| 27 | X | X | X | X | | | | | |
| 28 | X | X | | X | | | | | |
| 29 | X | X | | X | | | | | |
| 30 | X | X | | X | | | | | |
| 31 | X | X | X | X | | | | | |
| 32 | | X | X | | | | | X | |
| 33 | | | | | | | | | X |
| 34 | X | X | | X | | | | | |
| 35 | X | X | | X | | | | | |
| 36 | | X | | | X | | | | |
| 37 | | X | X | | X | | | | |
| 38 | X | X | X | X | | | | | |
| 39 | X | X | X | X | | | | | |
| 40 | | | X | | X | | | | |
| 41 | X | X | X | X | | | | | |
| 42 | X | X | X | X | | | | | |
| 43 | | | X | | X | | | | |
| 44 | X | X | | X | | | | | |
| 45 | | | | | | | X | | |
| 46 | | | | | | | X | | |

TABLE 6. RECOMMENDED TRAINING DEVICES VS BASIC OFFICER TRAINING OBJECTIVES (Continued)

| Training Objectives | Classroom | Library | Paper & Pencil Problems | Textbook | Individual Trainer (General and Specific) | Plotting Trainer | Fire Control Party | Periscope-Visual | Periscope-Mechanics |
|---|---|---|---|---|---|---|---|---|---|
| 47 | X | X | | | | | | | |
| 48 | X | X | X | X | | | | | |
| 49 | X | X | X | X | X | | | | |
| 50 | | | | | | | X | | |
| 51 | X | X | X | X | | | | | |
| 52 | X | X | X | | | | | X | |

requirements; i.e., the Mk 51 analyzer will be replaced by the Mk 81 Weapon Control Console with a CRT for MATE, Ray Trace, etc. To modify this simulator at the present time is unnecessary since the operational CRT analyzer has not yet been fully developed.

5.50 Future Mk 113 operator functions will require a higher level of mental processing than is required of present operational Mk 113 systems. This is due, in part, to the nature of the Mk 81 Weapon Control Console and its associated functions (MATE and Ray Trace). Thus, individual training devices will be necessary for Mk 81 operator training. The recommended generalized individual trainer utilizes a CRT display, similar to the Mk 81, and is capable of simulating each of the Mk 81's displays and functions. That is, aside from simulating present operational devices, the individual trainer is also designed to simulate MATE displays and operator functions. Thus, when the projected Mk 113 system changes are instituted in the mid 1970s, the generalized individual trainer will be completely compatible.

5.51 The potential of a trainer which utilizes a CRT is in its versatility and adaptability. Such a device is capable of simulating virtually any type of operational display, providing the physical screen dimensions are adequate. Fire control systems, beyond those presently projected, may be simulated by developing the appropriate software. Knobs, pushbuttons, etc, may be added or removed (within limits) with minor difficulty.

5.52 The generalized individual trainer is extremely flexible with regard to training techniques. Although it is advisable to implement adaptive individual training for several training objectives, the necessary variables have not yet been determined. The same reasoning holds true for implementation of machine scoring. Individual training, therefore, should be implemented on a group basis with several trainees individually solving the same problem on separate consoles. The instructor would randomly monitor each trainee and evaluate his final solution. This type of training would be similar to the present methods of individual plot training. After the necessary information is determined, however, machine scoring can be implemented, adaptive software developed, and adaptive training implemented. Also, each individual trainee could be working on a different problem based on his proficiency level. Eventually, interactive computer-assisted instruction (if and when it becomes feasible) could be implemented; the trainee not only uses the trainer as a device on which to develop and improve skills, but is taught by the device.

5.53 Programs can be set up to give a trainee as much or as little responsibility, diversity, and complexity in his problem tasks as is desired. Information fidelity and time can also be manipulated. Obviously, the uses of such a device are not limited to basic officer tactics training. The need for an individual trainer exists in other areas and at various levels. For example, this device could be used as a decision making trainer for advanced tactics training (i.e., PXOs, PCOs, etc). (Hammell and Mara, 1970; Sidorsky and Simoneau, 1970). It is beyond the scope of this report to detail the uses of a generalized individual trainer in other areas; however, the need does exist. Major modification of the trainer then would be confined to software.

5.54 Finally, in its desired form, the generalized individual trainer should have a library of programs and problems available. This device could be available to a variety of users, twenty-four hours a day. For example, during the evening periods, one man would be monitoring and operating the instructor's console, while several trainees could simultaneously take advantage of its availability to receive refresher or basic training. Two or more consoles could compete against each other in tactics, decision making, ship handling, etc; or two consoles could work together as a position keeper-analyzer team to solve a problem.

5.55 The generalized individual trainer fulfills a definite need in the present basic officer training program on a comparative cost effective basis. In addition, this device is amenable to many other present and future training needs in basic officer and other areas of training. The device is easily adaptable to changing operational hardware and training techniques. As such, it is a flexible and powerful training tool.

# SECTION VI

# RECOMMENDATIONS AND CONCLUSIONS

6.1 The present study identifies basic officer tactics training requirements in terms of training device specifications. As noted in the study (paragraph 3.36) the desired trainee output characteristics (i.e., basic officer requirements) are independent of the means by which they are obtained, and, thus, can be defined without regard to the structure of the training program. Device requirements, developed indirectly from the trainee output characteristics, were therefore determined independent of the training program structure. Existing devices were studied to determine their ability to fulfill the training needs. Modifications to existing devices, and new devices, were recommended to meet the device requirements not fulfilled by existing facilities. This section summarizes the device recommendations and conclusions, and makes training program recommendations for utilization of the devices.

## 6.2 DEVICE RECOMMENDATIONS AND CONCLUSIONS

1. Audio-visual aids should be implemented in the classroom in the form of slide-tape recorder lectures. These lectures should typically last for 10 minutes and be followed by a short discussion period. This method standardizes lectures, insures coverage of desired material, and presents visual aids.

2. Audio-visual aids should be provided in the library for individual viewing of the classroom lectures. The device should consist of an individual slide viewer automatically controlled by a tape recorder, and possessing headphones for the trainee. Trainees can review classroom lectures, view additional lecture material, etc, at their own rate.

3. It is recommended that a tactics manual be written specifically for the Mk 113 fire control system, as none presently exists.

4. The ability to degrade sonar information as a random function of S/N and delta bias error should be built into the Mk 113 attack center simulators. This should be accomplished on a software basis (i.e., modification of, and addition to, the existing computer program). In this way operators will be trained to use realistically degradable data.

5. System casualties and malfunctions should be introduced into the trainers. Hardware modification would be minor. Such occurrences would simulate real-world conditions, i.e., train the operator to expect and cope with malfunctions, and provide desirable stress in the training situation.

6. Degradable sonar information should be inputted to the bearing readouts used by plotters in a manner similar to that for the attack center simulators. The data source could be the CPU needed for the generalized individual trainer, or other existing computer facilities.

7. A periscope visual-task trainer is recommended for training the visual skills and knowledge associated with periscope usage. This desk top device should consist of a single eyepiece viewer similar to that on a periscope. Individual slides (photographs, illustrations, silhouettes, etc) should be presented, depicting what would be seen through a periscope under various conditions. The trainee should estimate range, masthead height, angle on the bow, etc. These devices could be used individually, or in a class where the instructor controls the exposure time. For example, training might be given for 15 minutes each morning. Thus, the visual periscope skills which develop through repeated practice would be developed separately from mechanical periscope skills, which require relatively less practice.

8. A generalized individual trainer is recommended to provide training in the skills and knowledge needed to effectively use the position keeper, angle solver, analyzer, and attack control console. This device is also recommended for meeting the projected individual training requirements of the Mk 51 Weapons Control Console (i.e., MATE, Race Trace, and displays on the Mk 113 Mod 10). Simulation and training is provided by individual operator consoles, each console containing a CRT and associated knobs and buttons. (For the functional specifications, see Appendix B.)

9. The generalized individual trainer is recommended to fulfill the need for a PK-analyzer subteam trainer. This device is also recommended as an advanced Tactics (and other division) trainer.

10. The present periscope facilities appear adequate for training the mechanical periscope skills required of basic officers.

## 6.3 TRAINING PROGRAM RECOMMENDATIONS

6.4 The following program recommendations center around the recommended devices and device modifications and the deficiencies noted during this study. (A summary of these recommendations is presented at the end of this section.)

6.5 Of foremost importance is the lack of objective performance standards throughout much of basic officer training. (This has been explained in detail throughout the report.) Because of this deficiency, automatic machine scoring cannot be developed at this time. It is recommended, therefore, that a study be undertaken to determine objective performance measures and standards for all areas of basic officer tactics training.

6.6 Present operator training combines both individual and team training with regard to Mk 113 system operation and TMA. One instructor cannot possibly handle ten trainees in a team situation and still provide them with immediate feedback concerning their performance. As a result, individual skills and knowledge cannot be developed properly. Team development is also hampered due to a lack of individual proficiency. It is recommended therefore that individual trainers be used to develop individual skills and knowledge, followed by the team trainer to develop interactive skills and knowledge.

6.7 Lack of proper teamwork and coordination in responding to an unanticipated event was observed in several training sessions and in an at-sea study (Pargo, 1968). This may be due to a lack of understanding of the team structure (i.e., how the team functions) and/or of the need for proper communications between team members, including development of team communication skills. These skills and knowledge can be adequately covered with the present team trainers, providing emphasis is placed on team and interactive skills and knowledge; i.e., providing individual skills and knowledge are adequately developed before initiating team training. Team training, such as communication and coordination, should logically follow, and build on, individually developed skills. It is recommended, therefore, that a program similar to that used by Siegel and Federman (1968) be instituted in basic officer training.

6.8 The present training methods rely on high time fidelity, since they consistently attempt to duplicate an operational situation. In many instances, such as in the earlier stages of individual and team training, high fidelity time is not necessary. For example, in training an operator to utilize a specific piece of information such as angle on the bow, several short (about 5 or 10 minutes) problems illustrating its use may be more advantageous than one long problem. In later stages of training, such as team interaction over the course of a complex fire control problem, time fidelity may be of more importance and, thus, should be included. It is therefore recommended that a study be undertaken to determine the importance of time fidelity in relation to specific training objectives throughout the basic officer training program. This study should be carried out in conjunction with the study recommended to determine performance measures, and should be oriented toward both individual and team training.

6.9 Stress is generally not implemented in basic officer training. It should be, however, especially in the more advanced stages of team training. Operators should be prepared to encounter the stress present in real-world operations. (Several methods of introducing stress were discussed earlier in the report.) To produce adequate stress, the problem must be short, and several stress-producing variables should be introduced simultaneously. In addition to producing stress, this type of training will prepare the basic officer for overcoming unexpected events (equipment malfunctions) which routinely occur in the operational environment.

6.10 The basic officer should be trained also to use imperfect data (i.e., degraded data). He normally encounters such data in the operational environment, and therefore should be faced with it in the training situation. Imperfect data should be introduced during both individual and team training, after the trainee has mastered the handling of perfect data.

6.11 The generalized individual trainer should be developed and used as a data collecting source on which to base training modifications. Although the individual trainer may not be utilized initially for individual adaptive training (i.e., utilized for individual training on a group-adaptive basis due to the lack of information concerning adaptive variables, etc), the training program can be gradually modified to include individual adaptive training. While the device is being used, adaptive variables may be determined through its use (Knoop, 1966). Thus, individual training should begin on a non-individually adaptive level and proceed to individual adaptive training as the training program is modified, and adaptive variables are determined.

6.12 Tactics training for basic officers places considerable emphasis on aspects of periscope usage. During wartime military activities when the primary mission of a submarine was to sink enemy shipping, the emphasis was on periscope usage. This is not the primary mission today; rather, subsurface ASW is the primary mission of the fire control party. Subsurface ASW relies heavily on passive sonar approaches (i.e., TMA utilizing passive sonar information). Although periscopes are used for surface approaches, target identification, etc, they are primarily manned by experienced personnel in a tactical situation (e.g., the CO). Basic officers would seldom use the periscope during a tactical encounter. Thus, it is recommended that less emphasis, relative to other aspects of TMA, be placed on periscope training in the basic officer curriculum.

6.13 In summary, the following training program recommendations are made:

1. Both individual and team training should be given separately, with team training following the development of individual skills and knowledge.

2. Team training emphasis (both in the classroom and on the device) should be placed on the development of communications, coordination, and other interactive team skills.

3. A study should be undertaken to determine the necessity of problem time fidelity with respect to individual and team training, and with respect to advancement in the training program (i.e., early phases of training to the later, advanced phases).

4. Stress (e.g., problem complexity and secondary task load) should be introduced into the training problem, especially in the advanced phases of individual and team training.

5. A study should be undertaken to determine objective performance measures and performance standards for all areas of basic officer tactics training, with attention given to their use in adaptive training.

6. Equipment malfunctions and casualties should be introduced in the latter phases of training to prepare the trainee for unexpected real-world occurrences.

7. Variable data (degraded) should be inputted in both individual and team training (i.e., following development of perfect data-handling skills) to train basic officers in the use of real-world data.

8. The generalized individual training device should be initially implemented on a group-adaptive basis. After modification of the training program, development of adaptive variables, and others, individually adaptive training should be implemented.

9. Following the development of performance measures, automatic scoring measures should be developed for the individual trainer.

10. Due to the infrequent requirement for a basic officer to use the periscope during TMA (i.e., experienced officers typically man the periscope during TMA), less emphasis should be placed on periscope training in the basic officer curriculum.

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# APPENDIX A

## TRAINING COURSE OBJECTIVES

## TRAINING COURSE OBJECTIVES

| Training Objectives | Conditions |
| --- | --- |
| 1. Develop proficiency in setting up and analyzing two- and three-dimensional geometrical problems to the extent where all target and own-ship parameters can be determined from combinations of other own-ship and target parameters. | 1. The skills and knowledge should be developed at a basic paper and pencil level without regard to TMA techniques or specific hardware. |
| 2. Develop understanding of the effects of target parameter changes on other target parameters to the extent that, given a dynamic situation, the trainee can predict how a change in any one (or more) target parameter will affect other target parameters. | 2. The understanding of parameter interrelationships should be on a qualitative and quantitative basis without regard to hardware or TMA techniques. This should provide the trainee with a concept of the interactions between the various target parameters. |
| 3. Develop an understanding of the measures and methods used in TMA (such as relative motion solutions, Eklund Ranging and Strip-plot solutions), including necessary information, assumptions, constraints, and limitations. | 3. An understanding of the theoretical usage of the various TMA techniques, their limitations, etc, without regard to specific hardware. Should show the interrelations among and between the TMA techniques and their development. |
| 4. Develop proficiency in selecting TMA techniques to fit various problem circumstances, making proper assumptions, etc, and solving the problems with the selected techniques. | 4. Given a theoretical problem consisting of a specific set of circumstances, the trainee must be able to evaluate the situation, select the most desirable TMA method (or methods), set up the problem, and solve for the desired target parameters; these skills need not be developed on specific hardware. Typical problems emphasizing various TMA methods should be given. Feedback should be given on procedural and decision-making performance. |

| Training Objectives | Conditions |
|---|---|
| 5. Develop knowledge on theoretical construction and usage of the time bearing, expanded time bearing, relative motion, and Mk 19 strip plots. | 5. Knowledge of the purpose, design, and construction techniques of each of the plots should be given. In addition, the conditions and methods of using the various TMA techniques by the plots should be given. Special emphasis should be placed on making the trainee aware of potential errors, deficiencies, and pitfalls associated with each of the plots. |
| 6. Develop proficiency in solving for desired target parameters using proper TMA methods on the:<br>Time Bearing Plot<br>Expanded Time Bearing Plot<br>Relative Motion Plot<br>Mk 19 Strip Plot | 6. This is essentially a combination of many of the skills and knowledge developed in 5. The trainee should receive realistic data, plot the data, evaluate the data, make assumptions, and solve for desired target parameters utilizing proper TMA techniques. He should receive feedback concerning both his decision-making and procedural performances. |
| 7. Develop knowledge of the duties and functions of every member of the plotting party (including Plot Coordinator). | 7. An understanding of the duties of every member should be developed, including the types of information he is responsible for, who he interacts with, and where he receives his information. The trainee should understand the overall objectives of the plotting party, how the individual functions combine to achieve those objectives, and the tasks desired of each individual position. |
| 8. Develop a knowledge of the duties on the navigation plotter as they relate to the navigation plot during an engagement with single and multiple targets. | 8. Understand the theoretical functions of the navigation plotter during an engagement, and his interaction with the plotting party. |

| Training Objectives | Conditions |
| --- | --- |
| 9. Improve proficiency in solving TMA problems involving various single and multiple target configurations as a team (plotting party). | 9. Each trainee should serve in all positions of the plotting party as problem-solving proficiency is improved. This is an exercise whereby individual skills are molded into team skills. Emphasis should be placed on problem solving as a team. |
| 10. Develop an awareness of the importance of functioning as a team (plotting party) and skill in doing so. | 10. Trainees should experience the duties of all the team members (including the Plot Coordinator) in solving problems as a team. Emphasis should be placed on interactive skills, such as communication and coordination, and developing an awareness of the functions and needs of other team members. Before beginning this objective, it is assumed that the trainees have already developed their individual plotting skills. |
| 11. Develop knowledge of capabilities, limitations, functions, and operating principles of the Mk 113 fire control console and its individual equipments. | 11. This is a broad brush, total picture, understanding of the Mk 113 fire control console. |
| 12. Develop knowledge as to the purpose, operating procedures, and problem-solving techniques on the PK and PK control section. | 12. The trainee should be instructed in the purpose, limitations, strong points, and capabilities of the PK so as to impart an understanding of the device. In addition, the trainee should be instructed so as to become knowledgeable in the operating procedures and TMA techniques (such as iterative solving techniques) utilized on the PK. This should be developed based on previously developed TMA techniques on the plots. |

| Training Objectives | Conditions |
|---|---|
| 13. Develop proficiency in using the PK, making proper assumptions, setting constraints, and solving for target parameters under various data conditions. | 13. The trainee must be presented representative information and allowed to make assumptions, etc, and solve for desired target parameters (should cover all types of encountered TMA techniques, including iterative solving). |
| 14. Develop knowledge as to the purpose, operating procedures, and problem-solving techniques used on the Mk 51 analyzer. | 14. This knowledge should involve the total operation and problem-solving methods utilized on the analyzer. It should include the use of previously developed TMA techniques. Also included should be knowledge of the analyzer's limitations, capabilities, strong points, use of constraints, and assumptions, as well as methods of use under various engagement situations. |
| 15. Develop proficiency in using the analyzer, making proper assumptions, setting constraints, and solving for target parameters under various conditions. | 15. The trainee must be presented representative information, allowed to make assumptions, set constraints, etc, and solve for desired parameters. The problems should be representative of solving for needed parameters, using operational TMA techniques. |
| 16. To provide knowledge of the duties of, and interaction between, the Analyzer Operator and the PK operator, as they apply to TMA. | 16. Knowledge should be gained in the classroom and should involve the operators' functions, duties, and interactions on an individual and overall level. |
| 17. Establish proficiency on the part of the PK and analyzer operators in working together as a team to solve TMA problems. | 17. Trainees should experience both positions of the PK analyzer team in solving TMA problems. The individual skills of each position should be molded to compliment the other position in solving TMA problems in the most effective and efficient way |

| Training Objectives | Conditions |
|---|---|
| | 17. (Cont'd) possible, utilizing the team capabilities. Emphasis should be placed on solving problems as a team. |
| 18. Develop knowledge of basic weapon course geometry. | 18. This is done in conjunction with development of basic TMA geometry and techniques. It should be accomplished on the paper and pencil level, imparting to the trainee knowledge of the basic weapon functions, attack geometries, general weapon maneuvering capabilities, etc. |
| 19. Develop knowledge of weapon types, capabilities, limitations, principles, and conditions of use as they pertain to usage by the fire control party. | 19. Theoretical knowledge of weapon types, their capabilities, etc, means of control, strong and weak points, and the relations between weapon types. In-depth study of weapons is conducted by the Weapons Division. |
| 20. Develop knowledge pertaining to usage of the various weapons, including launching and control procedures, and tactical and environmental considerations. | 20. This knowledge should be imparted with respect to both theoretical and hardware usage, mainly oriented towards tactical selection and launching procedures. |
| 21. Develop knowledge on the pros and cons of wire-guided weapons: when to use them, theories behind their use. | 21. Aimed at the differences between wire-guided and straight-running torpedoes. |
| 22. Develop proficiency in selecting weapons and determining weapon order parameters, weapon trajectory, and other relevant parameters for problem encounters. | 22. This should be accomplished on a paper and pencil level, allowing the trainee to select a weapon for a given situation and then calculate its parameters. |

| Training Objectives | Conditions |
|---|---|
| 23. Develop knowledge of the displays and functions of the angle solver and remaining sections of the Attack Director, including wire-guided torpedo control functions. | 23. Theoretical use of the angle solver according to design and operational usage doctrine. |
| 24. Develop proficiency in operating the angle solver section of the Attack Director. | 24. The trainee should develop proficiency in monitoring the displayed valves and lights, and in making wire guide corrections once the weapon has been launched. |
| 25. Develop knowledge of the displays and functions of the attack control console. | 25. Theoretical use of the attack control console according to design and operational usage doctrine. |
| 26. Develop proficiency in operating the attack control console. | 26. Proficiency should be developed in monitoring and analyzing the weapon status lights under various weapon conditions, as well as other necessary operating procedures such as shooting a weapon. |
| 27. Develop knowledge on the effects of sonar on the fire control problem. | 27. This should deal with the utilization of different types of sonar (active vs passive); ATF vs manual mode; the strong and weak points of both; limitations; and capabilities. Orientation should be towards their use on the various TMA methods previously developed, inherent variability in reception, and tactical and environmental considerations. Basic sonar is covered by the Operations Division. |
| 28. Develop knowledge on radar and ECM usage. | 28. This should be related to their use in TMA and the various methods previously developed, techniques of handling such data, and tactical consideration of use. Basic radar and ECM is given by the Operations Division. |

| Training Objectives | Conditions |
| --- | --- |
| 29. Develop knowledge of the basic types and functions of the periscope. | 29. The periscope types encountered on nuclear submarines, their advantages and disadvantages, etc, should be taught. |
| 30. Develop knowledge on the fundamentals of visual ranging techniques. | 30. This includes basic knowledge of triangulation, estimating angle on the bow and ship heights, and how basic visual TMA methods are developed. Should be on a paper and pencil level. |
| 31. Develop knowledge on the use of visual TMA techniques and periscope usage. | 31. Knowledge of TMA techniques (such as stadimeter and telemeter ranging, angle-on-the-bow estimates, etc) in context of proper usage procedures, and tactical and environmental conditions. |
| 32. Develop proficiency at estimating desired target parameters from visual information. | 32. Trainees should be proficient in estimating the necessary parameters from visual information. Realistic visual information should be presented for analysis. |
| 33. Develop proficiency in proper usage of the periscope, including proper coordination and communication. | 33. Develop coordination and communication skills in accordance with operating considerations for proficient use of the periscope. |
| 34. Develop knowledge of the duties and functions of the Fire Control Coordinator. | 34. On a functional level so that the trainee knows the FCC's duties. |
| 35. Develop knowledge of the duties and functions of the Approach Officer. | 35. On a functional level. |
| 36. Develop proficiency in analyzing a TMA problem from given parameters, i.e., conceptualizing. | 36. This proficiency should be developed without use of plots or graphical displays. |

| Training Objectives | Conditions |
|---|---|
| 37. Develop knowledge of, and proficiency in, target classification based on varying amounts and sources of data. | 37. This should involve techniques of classification such as periscope identification and frequency spectrum analysis. |
| 38. Develop knowledge on normal cruise tactics. | 38. Knowledge should be developed on normal cruise tactical procedures for ship handling, use of sensors, system status, trailing tactics, and other procedures. |
| 39. Develop knowledge on approach and attack tactics. | 39. Including sonar (active and passive) approach, periscope and radar approaches, employment of weapons, and evasion. |
| 40. Develop proficiency in evaluating a situation from given data, making proper assumptions, and selecting proper tactical responses. | 40. Should be conducted on both paper and pencil and high fidelity level. This involves both evaluation and projection of the tactical situation on the part of the trainee, mostly decision-making performance. |
| 41. Develop knowledge of own-ship maneuvering performance and capabilities as they pertain to tactics, including their effect on (or necessity for) TMA solutions, evasion, normal cruise, and approach and attack. | 41. Should be oriented toward ship maneuvering as it affects TMA, weapon order generation, and other tactical considerations. The basics of own-ship maneuvering are covered by the Executive Division. |
| 42. Develop knowledge of environmental conditions on TMA and tactics. | 42. This should pertain to the effects and use of environmental conditions as they apply to TMA, tactics, etc, including the use of ray trace and SVP, and effects of thermal layers. |
| 43. Develop proficiency in utilizing environmental information (e.g., SVP) in TMA. | 43. Theoretical definition and operational usage of environmental data in TMA. |

| Training Objectives | Conditions |
|---|---|
| 44. Develop knowledge of the functions performed by, and the interactions between, the plotting party, the Mk 113 operators, FCC, and AO in TMA, weapon order generation, and ship control. | 44. Theoretical knowledge of the total team's makeup in relation to accomplishing TMA; how each operator fits into the total picture, desired information flow, communications, etc. |
| 45. Develop proficiency in working as a total fire control party for TMA, weapon order generation, tactics, etc, during typical approach and attack missions. | 45. This proficiency should be developed as a team to solve all aspects of the fire control problem. Trainees should experience all positions, developing a knowledge of the team interaction and proficiency in working as a team to achieve desired goals. Emphasis should be placed on utilizing individual skills as a team in making various types of approach and attack. |
| 46. Develop an awareness of the importance of functioning as a team (fire control party) and skill in doing so. | 46. Emphasis should be placed on team interactions, including communication, coordination, and awareness of their team members' needs, functions, etc (for improving team proficiency). |
| 47. Develop insight into the trainee's performance, proficiencies, deficiencies, communication, etc, in his capacity as a team member and decision maker. | 47. In a team situation, each trainee must be provided the necessary information to evaluate his own performance (develop insight). |
| 48. Develop knowledge on the casualty usage of the fire control system (Mk 113, plots, etc). | 48. This should develop knowledge of alternate methods, partial equipment usage, tactical considerations, etc. |
| 49. Develop knowledge on, and proficiency in, basic troubleshooting of fire control system hardware. | 49. Sufficient knowledge to perform minor tests on equipment, recognize deficiencies, and make minor repairs or corrections prior to and during operation. |

| Training Objectives | Conditions |
|---|---|
| 50. Develop proficiency in adapting to emergency (unexpected) situations. | 50. This should be developed in a high fidelity atmosphere, and should consist of introducing unexpected problems requiring immediate attention. These problems may conflict with the present mission, interfere with it, and/or be completely unrelated. They should require extensive consideration from various team members so as to develop adaptative skills and induce stress. |
| 51. Develop abilities in ship identification, surface and submerged; determine friend or foe. | 51. This would pertain to ship silhouettes, noise characteristics, information aiding the determination of periscope ranges, etc. It should consist of up-to-date intelligence information. |
| 52. Develop proficiency in identifying ships, classes, etc, based on available data (periscope and sonar). | 52. Both pictoral and silhouette information should be provided from which trainee can identify the ship's class and other desirable parameters. |

# APPENDIX B

## FUNCTIONAL SPECIFICATIONS

B.1 This appendix contains functional specifications for the generalized individual trainer, each trainee console, and each intended display. Because of the classified nature of the operational displays, no illustrations are given depicting actual display designs. A hypothetical example is given however.

B.2 Also contained in this appendix is a recommended computer system functional design for meeting the device requirements.

B.3 FUNCTIONAL SPECIFICATIONS

B.4 GENERALIZED INDIVIDUAL TRAINER. The generalized individual trainer should consist of ten individual operator consoles and one instructor console; the instructor console's should be identical to an operator's console. Its overall function is to provide individual training in accordance with several different training system needs. An illustration of a typical CRT layout applicable to each display is given in figure 6; target readouts are shown on the CRT in a manner similar to the operational device. Thus, operational digital readouts should appear as digital readouts on the CRT, dials appear as dials, etc. In addition, they should appear in the same relative position on the CRT as on the operational device. Note how the selector switch for the active or passive sonar mode is simulated. The choice of sonar mode can be effected in any of three ways: (1) point the light pen at the desired selector switch position (e.g., Active Sonar); (2) turn the center knob below the CRT to position the indicator; or (3) select the sonar mode by pushing the appropriate function button. The method to be used depends on which one provides the closest approximation to the operational system task. This selection must be made by the training specialist and programmed into the computer. The knobs not in use for a particular display should be covered or otherwise removed. An overlay over the keyboard would specify the function of each button and could be easily changed when the function changes.

B.5 The displays for operational devices should be formatted in a manner similar to the above example, with the specific design depending on the device being simulated, the problem, etc.

B.6 The following is a list of functional specifications for the generalized individual trainer.

1. Each console must be able to function independent of the other consoles.

2. Each console must be capable of being operated simultaneously and independently.

3. The computer facilities must be capable of providing individual adaptive training to each console, providing the necessary software is developed.

4. The computer facilities must be capable of maintaining real-time, trainee-input response and display update (10 cps) on the ten consoles simultaneously.

5. The computer facilities must be capable of monitoring and scoring trainees on a continuous basis, providing the necessary software is developed.

6. The computer facilities must be capable of being expanded to adequately control up to 20 individual consoles.

7. The computer facilities must be adaptable to disk storage (for eventual development of a program library).

8. The computer facilities must have proper control equipment and excess input-output channels for interfacing with other devices (e.g. present team trainers) and/or feeding other readouts (such as plot readouts).

9. Two or more consoles must be capable of working together on a single problem (each console having different or similar functions) or opposing one another.

B.7 TRAINEE CONSOLE FUNCTIONAL SPECIFICATIONS (Refer to Figure 6).

1. Each console should have a CRT for information display and other input-output functions.

2. Knobs and pushbuttons should be available for trainee inputs, their locations and functions as specified in the particular display design.

3. Light pen control should be provided the trainee to implement actions, ask for data, indicate choices, etc.

4. The display should update, in real time (10 cps), in response to trainee inputs.

5. The respective displays and controls should functionally simulate the operational ones, but not duplicate them.

6. Sources of external information should be made available (e.g., on the CRT).

7. It should be capable of simulating the position keeper, angle solver, analyzer, attack control console, and projected future devices (e.g., MATE).

8. The upper portion of the CRT should simulate the desired operational display. The lower portion of the CRT should display additional information, sources of additional information, knowledge of results (feedback), instructions, question answers, etc.

9. Each console should be capable of accepting an overlay to simulate, more exactly, certain devices (e.g., analyzer readouts).

10. Knobs not presently being used should be capable of being covered.

B.8 POSITION KEEPER DISPLAY FUNCTIONAL SPECIFICATIONS (Refer to Figure 6).

1. The upper part of the CRT (about 70 percent) should simulate the PK readouts.

2. The three knobs on each side of the CRT serve as PK manual input knobs, for entering data (constraints) and iterative solving.

3. The lower five knobs should not be used and should be covered.

4. The lower portion of the screen is reserved for additional displays (e.g., cuing and information sources).

5. The trainee can ask appropriate questions (e.g., angle-on-the-bow estimate from FCC) by quizzing the CRT with light pen, providing a provision has been made on the screen (e.g., AOB FROM FCC).

6. Pushbuttons can be used for functions (e.g., clearing PK) that rarely occur.

7. Problem type, parameters, objectives, etc, should be determined by a training specialist.

B.9 ANALYZER CONSOLE FUNCTIONAL SPECIFICATIONS (Refer to Figure 6).

1. The upper part (about 70 percent) should simulate the input and output sections of the analyzer.

2. Directly underneath the I-O sections should be the control section, simulating the analyzer control section. Control selection and positioning should be controlled by pointing the light pen at the desired switch position.

3. The three knobs on either side of the CRT serve as manual input controls on the analyzer.

4. The lower five knobs should not be used and should be covered.

5. The lower portion of the screen is reserved for additional displays.

6. The trainee may quiz CRT (i.e., ask for information, etc), providing appropriate provisions are made in the program and on the CRT.

7. Pushbuttons may be used for functions that seldom occur.

8. Problem type, parameters, objectives, etc, must be determined by a training specialist.

B.10 ANGLE SOLVER FUNCTIONAL SPECIFICATIONS (Refer to Figure 6).

1. The upper portion of the CRT (about 70 percent) should simulate angle solver readouts.

2. The top knobs on each side of the CRT should not be used.

3. The lower two knobs on each side of the CRT serve as manual input knobs for entering data such as own-ship depth.

4. The two end knobs, below the CRT, should function as manual input controls.

5. The middle knob, below the CRT, should function as a manual input control.

6. The remaining two knobs below the CRT should not function and should be covered.

7. The lower portion of the CRT is reserved for additional displays such as cuing.

8. Operator functions that seldom occur can be effected by the function push-buttons.

9. The trainee can ask appropriate questions by means of the light pen.

10. Problem parameters, etc, should be determined by a training specialist.

B.11 COMPUTER SYSTEM

B.12 Several computer system designs were considered for the trainer, consisting of (1) a CPU directly controlling the individual consoles; (2) a CPU controlling small satellite computers which, in turn, directly control the consoles; and (3) a complete individual computer for each console. The third alternative was rejected because an adaptive program would require a large amount of storage and logic, needing duplication for each device, and a CPU provides a central communications link between consoles. Of the other two alternatives, the first was selected because the satellite computers are not really necessary, and thus, need not be included (i.e., effectiveness is the same at a lower cost). Engineering characteristics for both of these systems are given in the paragraphs following.

B.13 CPU DIRECTLY CONTROLLING INDIVIDUAL CONSOLES. This system consists of a CPU such as Univac 642-B which generates all own-ship, target, and display parameters, and teaching logic and scoring data. (See Figure 7.) The output data would be stored in a display buffer and independently outputed to each console under control of the display clock. The display refresh should be at 40 frames per second, with individual displays outputing up to 500 characters. Thus, the display clock rate should be 200 kHz.

B.14 The console knobs should be of an analog type (to lower cost) and multiplexed at a rate of 10 per second. Thus, for 110 knobs (i.e., 11 knobs per console), the multiplexer and A/D converter must operate at 1100 Hz.

B.15 Keyboard functions should be multiplexed and handled on a priority basis, and acknowledged via illumination cues.

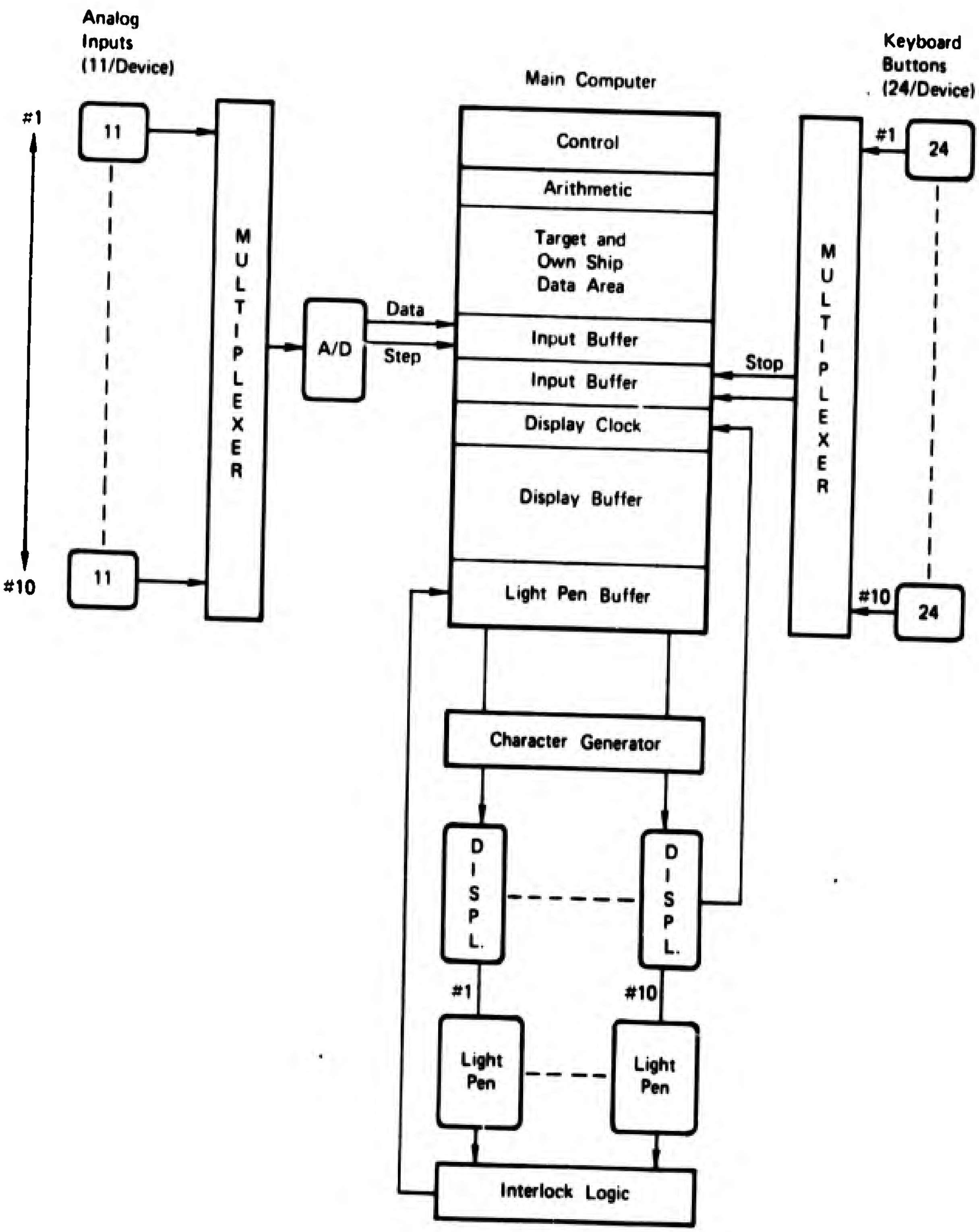


Figure 7. CPU Directly Controlling the Individual Consoles

B.16 A typical list of hardware with estimated cost is given below.

| | | | Cost ($) |
|---|---|---|---|
| 1. | Central Computer (one required, such as 642-B) | | 125,000 |
| | a. Control unit | | |
| | b. Arithmetic unit | | |
| | c. Data storage | | |
| | d. Input buffer for analog knob input | | |
| | e. Input buffer for keyboard inputs | | |
| | f. Display output control clock | | |
| | g. Display buffer | | |
| | h. Light pen buffer | | |
| 2. | Display Consoles (10 required) | | 17,330 |
| | a. 21" CRT display | 14,000 | |
| | b. 11 manual entry analog input devices | 330 | |
| | c. 24-function keyboard | 500 | |
| | d. Character and vector generators | 2,000 | |
| | e. Light pen | 500 | |
| 3. | Multiplexer | | 5,000 |
| | a. For analog inputs | 2,500 | |
| | b. For keyboard inputs | 2,500 | |
| 4. | Tape Reader | | 2,500 |
| 5. | Tape Punch | | 3,000 |
| 6. | AD Converter | | 2,500 |

B.17 CPU WITH SATELLITE COMPUTERS CONTROLLING INDIVIDUAL CONSOLES. This system utilizes hardware similar to the system in Section B.13, with the exception of an additional satellite computer at each console (figure 8). The satellite computer updates the display, based on information from the CPU. When the display parameters from the CPU do not change, the satellite computer can independently update the display. Thus, the CPU has more available time for other functions. In contrast to the previous system, the main computer-generated information is coupled to the individual displays via hardware rather than software.

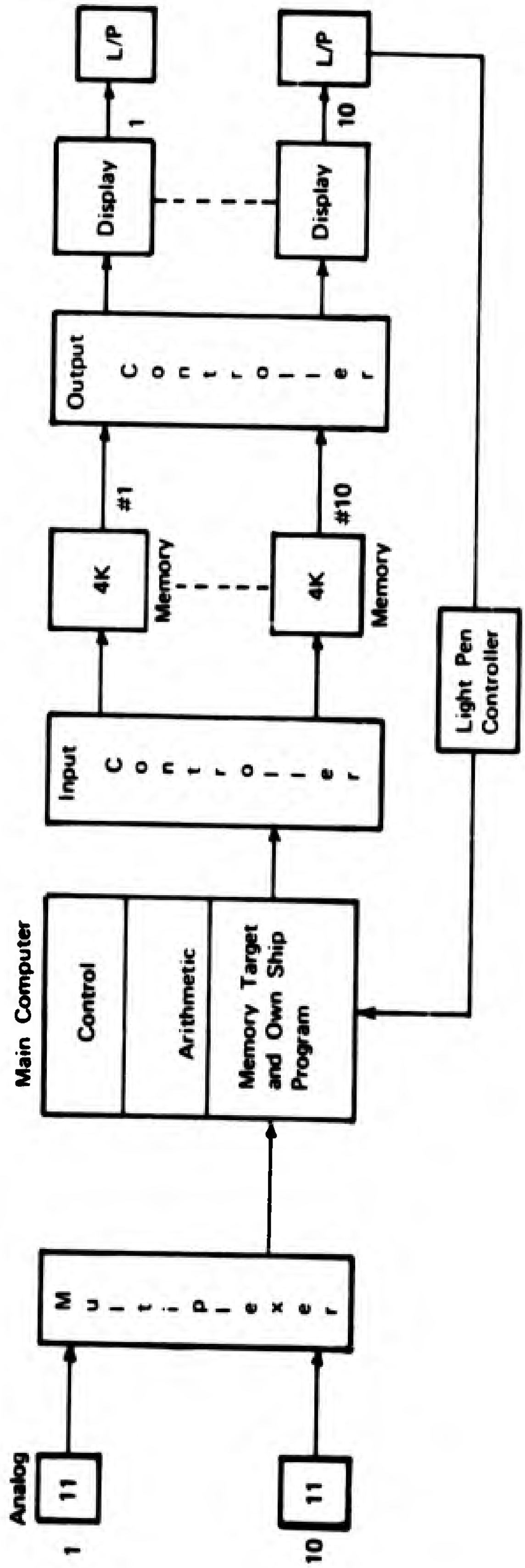


Figure 8. CPU and Satellite Computer Control of Display